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This study was conducted to determine the effects of backpack frame length and pack load on the movement capabilities of men and women. The tests included walking on a treadmill at 5.6 km/hr, an agility run around obstacles, and ladder climbing. Performance data were recorded before and after two, 20-minute periods of overground walking at 5.6 km/hr. Seventeen men and 16 women were tested under eight combinations of frame length and pack load. The men used frame lengths of 18, 20, 22, and 24 inches, while those used by the women were 16, 18, 20, and 22 inches. The pack load —

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conditions included a common load for the men and the women of 26 kg and a second load of 33 kg for the women and 40 kg for the men. Time to complete the agility run and the ladder climb increased significantly as load was increased. Increased load also produced significant modifications in the mechanics of walking. Analyses of frame effects indicated that agility run and ladder climb scores tended to be somewhat better under the longer than the shorter frame lengths. However, changes in frame length resulted in only minor modifications in walking patterns.

PREFACE

This is the final report of research performed under Contract Number DAAK60-81-C-0018 with the Individual Protection Laboratory, U.S. Army Natick Research and Development Laboratories, Natick, Massachusetts. It contains a discussion of the procedures and results for this project on the Biomechanics of Load Carrying Behavior. The work was formulated and directed by Drs. Carolyn K. Bensel and Richard F. Johnson, Human Factors Group, Individual Protection Laboratory. Dr. Bensel was the contract monitor and Dr. Johnson was the alternate.

The authors would like to express their appreciation to several individuals for their assistance during this project. Ms. Melanie Hunt, Ms. Teresa Winter, and Mr. Liu Zhi Cheng provided their talents during the data collection and data processing phases of the project. Mr. John Palmgren and Mr. Joe Johnstonbaugh provided technical assistance for various aspects of the project. Ms. Catherine Lendrim handled many of the administrative and secretarial functions associated with the project. Dr. Elsworth R. Buskirk, Director of the Laboratory for Human Performance Research, made available the treadmill used in the walking analysis. Finally, Lt. Col. Arthur S. Dervaes III, Professor of Military Science, assisted the experimenters in obtaining subjects for the study and in providing use of the test facility. The cooperation of these individuals and the quality of their assistance was greatly appreciated.

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Effects of Backpack Frame Length, Pack Load, and Participation Time on the Physical Performance of Men and Women

INTRODUCTION

During the last several years, the U.S. Army Natick Research and Development Laboratories have sponsored several research projects that have focused on various aspects of load carrying behavior. These projects have examined the relative performance of men and women, the influence of systematic load increases on several types of physical performance, and the effect of backpack design and loading on performance measures and on the inertial properties of a carrier-backpack system. The most recent of these projects focused on a previously unstudied factor, frame length, to determine its influence on load carrying behavior.[1] In that study, the frame size used with the current Army load carrying system, the All-Purpose Lightweight Individual Carrying Equipment (ALICE), was directly related to body size in an effort to determine if frame length had an influence on performance. The results yielded very few significant effects due to frame length, although the relatively short frames had a small detrimental effect on performance. The testing for this earlier study considering frame length effects was done with the subjects in a non-fatigued state and carrying a moderate load. Based on the results, it was suggested that frame length effects may be quite small unless the carrier is in a fatigued state or is carrying a heavy load.

The present study was an attempt to extend the research on the frame length question to include the influences of load and fatigue. Rather than tie the frame length directly to body size as was done in the earlier study, absolute frame sizes were used in this study. It was felt that this approach would more clearly establish whether or not a single frame length is adequate for both males and females of the military population, and if it is, whether the current standard frame length of 20 (50.8 cm) inches is the most appropriate length.

EXPERIMENTAL PROCEDURES

Subjects

Seventeen men and sixteen women whose mean age was 20.9 years served as subjects for the study. All were students in the Army R.O.T.C. Program at Penn State University. Because of their military experience, their interest in the research, and their previous exposure to some of the equipment used in the study, they were considered to be well suited for the research project. It was further believed that these subjects represented a group of highly motivated individuals who gave their best efforts throughout the testing.

[1] Martin, P.E., R.C. Nelson, and I.S. Shin. Effects of Gener, Frame Length, and Participation Time on Load Carrying Behavior (Tech. Rep. NATICK/TR-82/041). Natick, Massachusetts: U.S. Army Natick Research and Development Laboratories, August 1982.

The body size and dimensions of all subjects were estimated using a series of fifteen anthropometric measures. These measures were then used to perform a detailed examination of the representativeness of the sample subjects with respect to the military population. This was done by statistically comparing the mean values of each anthropometric variable for the male and female subjects of the sample with the published data of White and Churchill[2] and Churchill, Churchill, McConville, and White.[3] These data were considered to adequately represent the military population since they were based on very large sample sizes. The results of these statistical comparisons will be considered in detail later in this report.

Frame Conditions

The ALICE load carrying system currently in use by the U.S. Army consists of two components, a pack made of nylon duck and nylon webbing and an external aluminum tubing frame. Two different packs, one with a carrying capacity of approximately 32 kg and the other with a capacity of approximately 23 kg, were developed as part of the ALICE system. The pack with the lesser capacity was used in this study. The standard frame incorporated into this system is 20 inches (50.8 cm) in length. In this study, however, each subject completed the testing using four different backpack frame lengths. As previously noted, an earlier study by Martin, Nelson, and Shin (ref. 1) examined the influence of frame length variations on physical performance. Frame lengths were directly related to the anthropometric measure waist back length such that each person was assigned a personalized frame size. The mean personalized frame length was found to be 19.7 inches (50.0 cm) for the men and 18.6 inches (47.2 cm) for the women.

Rather than assign frame lengths to each subject on an individual basis based on body size, the present study used absolute frame lengths. The women used frame sizes of 16, 18, the standard 20, and 22 inches (40.6 cm, 45.7 cm, 50.8 cm, and 55.9 cm, respectively). The men used lengths of 18, 20, 22, and 24 inches (45.7 cm, 50.8 cm, 55.9 cm, and 61.0 cm, respectively). As can be seen, three of the four frame lengths used in this study were common to both the male and female subjects which allowed for performance comparisons of the two sexes at these three frame lengths. Based on the mean values for personalized frame length determined by Martin et al. (ref. 1), it was believed that the male and female subjects would be better represented by slightly different ranges of frame lengths. It was felt that this would allow the male and female subject groups to be adequately tested with frames which covered a range from being relatively short to relatively long.

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[2]White, R.M. and E. Churchill. The Body Size of Soldiers: US Army Anthropometry - 1966 (Tech. Rep. 72-51-CE). Natick, Massachusetts: U.S. Army Natick Laboratories, December 1971.

[3]Churchill, E., T. Churchill, J.T. McConville, and R.M. White. Anthropometry of Women in the US Army - 1977: Report No. 2 - The Basic Univariate Statistics (Tech. Rep. NATICK/TR-77/024). Natick, Massachusetts: U.S. Army Natick Research and Development Command, June 1977.

The frames used in this study were identical in construction with the exception of the length differences. Each frame, regardless of length, attached to the pack in a similar manner such that the top of frame essentially coincided with the top of the pack. This was so because the shoulder straps attached to the top of the frame and at the same time tended to fix the position of the frame relative to the pack. Additional straps on the pack attached to the frame near its bottom which further stabilized the pack on the frame. Because of this frame-pack arrangement, the major difference between the frame length conditions was the position where the lower portion of the frame, a padded waist belt, made contact with the body. The shorter frames tended to contact the body in the lower back region whereas the longer frames tended to contact the body in the pelvic region.

Load Conditions

In addition to examining the influence of frame length, the effect of load was also considered in this study. All subjects completed each of the four frame length conditions under two loads. This meant that each subject completed a total of eight test sessions, one for each frame-load combination. The load conditions used in this study were nearly identical to loads used in a previous investigation by Nelson and Martin.[4] The first of these loads had a mass of approximately 26 kg, including all clothing and equipment worn or carried by the subject, and served as a common load condition for men and women. For this particular load, the subjects wore underwear, socks, utility shirt, gym shorts, combat boots, a PASGT helmet, and the standard ALICE fighting gear. The fighting gear included a water-filled canteen with its cover, an intrenching tool with carrier, and two small arms ammo cases containing 1.75-kg sandbags. The total weight of the fighting gear was 6.65 kg. The subjects also carried a simulated M-16 rifle, which weighed 3.17 kg, and the ALICE load carrying system. The pack, which weighed 1.10 kg, was loaded with Army clothing and equipment items totalling 9.07 kg. The items in the pack included a cold weather sleeping bag, a pneumatic matress, a rain poncho, socks, an undershirt, and a waterproof clothes bag.

In addition to this load condition, the men and women completed the testing with a second load condition which was different for the two sexes. To obtain the second load condition for the women, an additional 6.8-kg mass was placed in the pack, making the total load for this condition approximately 33 kg. For the men, the second load condition was formed by adding an additional 13.6-kg mass to the pack, thereby making the total load for the second condition approximately 40 kg. These additional masses were in the form of barbell disks and were positioned such that they were along the edge of the pack closest to the body.

[4]Nelson, R.C. and P.E. Martin. Volume I. Effects of Gender and Load on Combative Movement Performance (Tech. Rep. NATICK/TR-82/011). Natick, Massachusetts: US Army Natick Research and Development Laboratories, February 1982.

Testing Protocol

Each subject attended ten experimental sessions over a six week period. These sessions can be classified into three categories: orientation, testing, and anthropometry. The first of the ten sessions served as an orientation for the subjects. During this session, the subjects were informed of the nature of the study, the general procedures to be used in the testing, and the potential risks involved. Informed consent was then obtained from each subject. In the remaining portion of the orientation, the subjects practiced the performance tasks to be tested. These included treadmill walking and two combative movement performance tests.

The next eight experimental sessions were those in which performance measures were collected for the eight frame length-load combinations used by all subjects. These performance measures were based upon two types of tests. The first involved two combative movements used in previous load carrying experiments (ref. 1 and 4) and the second involved film analysis of gait during treadmill walking. The procedures used to analyze walking performance were also developed in one of these earlier studies (ref. 1). The sequence of testing used in each test session was arranged such that repeated measures of subject performance were obtained at different times during a test session. It was believed that the demands placed on the subjects during each session would result in some degree of fatigue which might help to accentuate the influence of frame length on performance. The standardized sequence of testing used in each test session, the performance tests, and the walking analysis procedures will all be described in more detail later in this report.

The tenth and final experimental session was one in which the body size and dimensions of the subjects were estimated using a series of fifteen anthropometric measures. These included stature, body mass, waist back length, cervicale height, shoulder height, crotch height, waist height, buttock height, sitting height, shoulder circumference, chest circumference at scye, chest/bust circumference, waist circumference, hip circumference, and interscye breadth. With the exception of waist back length, all measures were performed in accordance with the measurement definitions provided in the 1966 and 1977 reports of the anthropometry of U.S. Army men and women (ref. 2 and 3). These measures allowed for a detailed examination of the representativeness of the sample subjects with respect to the military population. The waist back length definition differed slightly from those used in the 1966 and 1977 reports but was identical to that used by Martin et al. (ref. 1) in their work on load carrying behavior. Appendix A contains the definitions and measurement procedures for each of the fifteen anthropometric measures.

Physical Performance Tests

The combative movement tests selected for use in this study represent a small subset of those tests used in an earlier study by Nelson and Martin (ref. 4). These included an agility run and a ladder climb test and are described as follows:

Agility Run. A series of four padded circular obstacles 106.7 cm high with a diameter of 20.3 cm was placed 304.8 cm apart with the first located 304.8 cm from the starting line. Each subject initiated a trial upon their own volition. As the subjects left the starting line, they broke a beam of a photocell system which started an electronic timing unit. All subjects were instructed to pass on the right side of the first obstacle, to weave through the remaining obstacles, passing around the last obstacle, and then to weave through the obstacles on the return to the starting area. The timer was stopped when the subjects broke the beam of the photocell system a second time as they passed through the starting area on the return. The subject performed two trials in succession and the mean of these two trials was used in the statistical analysis.

Ladder Climb. A vertical ladder 5.5 m high with rungs 57.2 cm wide and 30.5 cm apart was constructed for this test. Subjects assumed a starting position in which the left foot was placed on the first rung of the ladder and the right foot held down a foot switch. The subjects were allowed to position their hands in a manner which was comfortable to them. They started upon their own volition and, by releasing the foot switch, triggered an electronic timing unit. They were instructed to climb up the ladder as quickly as possible with an alternating step technique, which assured that foot contact was made with each rung. The ladder was instrumented with a photocell system such that the timer was stopped when the subject's foot broke a beam at the level of the ninth rung (304.8-cm level). Once again the subject performed two trials in succession and the mean of these two trials was used to represent a subject's performance in the statistical analysis.

Film Analysis of Walking

Standard high speed cinematography procedures were used to film the subjects as they walked at 5.6 km/hr on a motor-driven treadmill. A single Locam camera manufactured by Redlake Corporation was used in the filming. All movements under investigation were assumed to occur in a single plane and thus a planar analysis was completed. The camera speed was preset to run at 50 frames per second and was subsequently calibrated in the analysis procedures. This was done by positioning a timing display unit which was manufactured in The Pennsylvania State University Biomechanics Laboratory such that it was in the field of view during all film trials. Reference numbers were also placed in the field of view to assist in the identification of the subjects and trial conditions.

The films were analyzed using a Vanguard projection system and a Bendix digitizer. This system provided on-line data recording capabilities on the laboratory computer, a Digital Equipment Corporation PDP 11/34 mini-computer. Each film period was kept as brief as possible to keep film usage to a minimum but was generally long enough to capture two complete step cycles. Because of the large amount of digitizing required, only a single step cycle was analyzed. Consequently, two strides were digitized for each trial which provided two measures of each variable used to describe the walking patterns of the subjects. The mean value of these two strides for each variable was used in the statistical analysis.

The film analysis procedures used to analyze the walking patterns of the subjects provided values for six variables which described important temporal and kinematic characteristics of gait. These values were obtained by digitizing the locations of four body points at several critical body positions during the step cycle. These four points were estimates of the locations of the ankle, knee, hip, and shoulder joint centers. The body positions at which these estimates were made included the positions of contact of the right heel, removal of the left toe from contact, contact of the left heel, and lifting of the right toe from contact. These positions, which were analyzed over two strides, served to subdivide the step cycle so that measures of the six variables could be obtained. The following definitions of these variables are provided.

1. <u>Stride length</u> in meters was measured as the distance from the point of one heel strike to the point of the next heel strike.

2. <u>Stride rate</u> was calculated by measuring the stride time which was the time between two heel strikes, and then taking the reciprocal of the stride time. Stride rate was then represented as the number of strides completed per second.

3. <u>Single leg contact time</u> was measured as the time from heel strike of one leg until the foot of the same leg left the ground to begin the swing phase.

4. <u>Swing time</u> was the time of non-support for one leg and was measured from a point when the foot of one leg left the ground until heel strike of the same leg.

5. <u>Double support time</u> was the time during which both feet were in contact with the ground. This was the time from heel contact of one leg until the foot of the other leg left the ground.

6. <u>Trunk angle</u> was a measure of the forward inclination of the trunk at a point when the foot of one leg left the ground. The angle measured was that between the horizontal and a line connecting the shoulder joint and the hip joint such that a greater forward inclination of the trunk resulted in a smaller value for the angle.

<u>Individual Test Session Protocol</u>

As was previously noted, the subjects completed eight test sessions, one for each frame length-load combination. For each subject, the order of presentation of these eight frame-load conditions was randomly determined using a computer program that was designed to generate random orders of a specified sequence of numbers. This was done in an attempt to eliminate any possible order effects that may have been produced by using a fixed sequence of conditions. All test sessions were nearly identical in terms of the types of testing done and the sequence and timing of the tests. The test sessions were designed to last 55 minutes and to provide three separate examinations of the combative movement performance tests, the agility run and the ladder climb. These were separated by two, 20-minute periods in which both treadmill and overground walking were completed and in which two samples of treadmill walking were collected. Figure 1 provides a line graph which describes the timing of each individual test session.

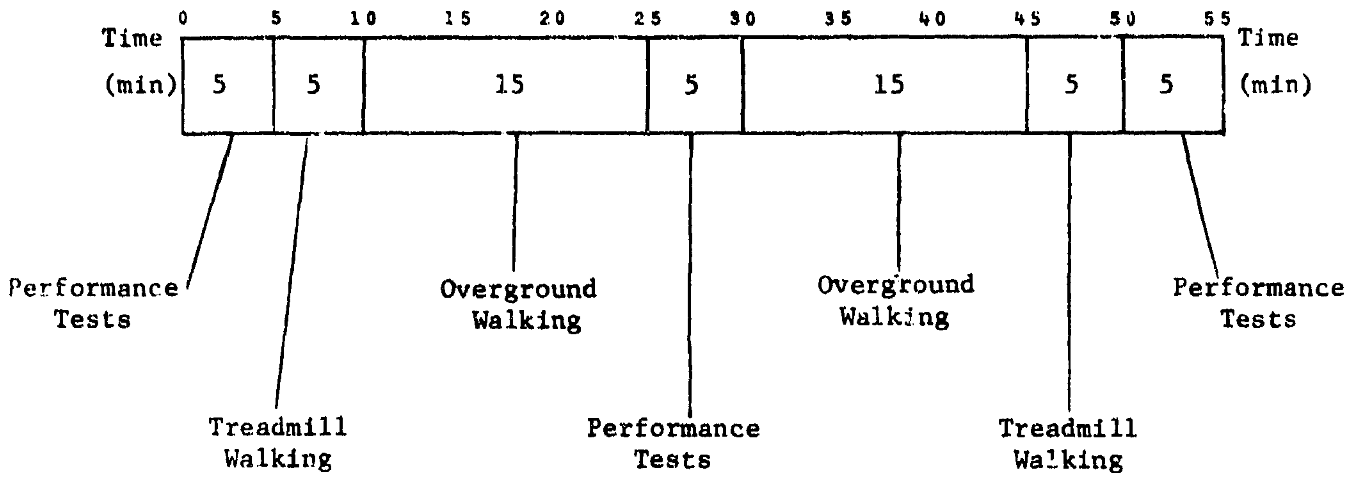

Figure 1. Temporal basis for the experimental test sessions.

The subjects began each session with a two-minute warmup consisting of jogging and stretching exercises followed by two trials of the agility run and two trials of the ladder climb. They then proceeded to the treadmill for a five-minute walking session at 5.6 km/hr. After four minutes and 30 seconds on the treadmill, a three-second burst of film was taken. Following treadmill walking, the subjects walked overground for fifteen minutes. During this time, they were paced so that their walking speed closely matched their speed of walking on the treadmill. No data collection was performed during the overground walking. This activity was meant to increase the physical demand placed on the subjects and to increase the time between the repeated measurements of the performance tests and treadmill walking. Following the overground walking period, the performance tests were repeated for the second time. This was then followed by 15 minutes of overground walking and 5 minutes of treadmill walking. The second film sample, three seconds in duration, was again taken four minutes and 30 seconds after the initiation of treadmill walking. The test session was then completed with a third set of measurements on the performance tests.

Statistical Procedures

The design of the experiment allowed for the examination of the influence of several factors on treadmill walking and combative movement performance. These factors included gender, frame length, load, and participation time. The latter was an attempt to examine how performance may have changed with respect to time within a test session as the measurements were taken two and three times for walking and the performance tests, respectively.

The majority of the statistical analyses performed in this project involved the use of analysis of variance. The program ANOVR, originally created by Gordon F. Pitz of Southern Illinois University and modified by Dr. Paul A. Games[5] of The Pennsylvania State University, was used to analyze the walking and performance test data. Follow-up analyses using the Tukey Wholly Significant Difference (WSD) test were performed to determine where significant differences between mean values existed when significant F-values were found in the ANOVR procedures.

Because certain frame length and load conditions were common to both the men and women and others were different, two separate three-factor designs were used in the statistical analysis. The men and women completed the testing with two loads, but only one (26-kg condition) was common to both sexes. In addition, four frame length conditions were used by both the men and women. Three of these (18, 20, and 22 inches) were common to both, and one (16 for the women and 24 for the men) was different. Consequently, one design examined the effects of frame length, load, and participation time for the men and women separately. The second design considered the effects of gender, frame length, and participation time for the common load and the common frame lengths used by the men and women.

A conventional ANOVA logic was used to assess the results of the analyses. By this logic, the test for a three-factor interaction was first examined. If the result of this test was a significant F-value, then the data were split on one factor and reanalyzed at each level of that factor in a two-factor design. If the three-factor interaction was nonsignificant, the three, two-factor interactions were considered next. The presence of a significant two-factor interaction was then followed by an examination of simple means of one factor at levels of the other factor involved in the interaction. Only if a factor was not involved in either a three-factor or a two-factor interaction were the main means for that factor considered in a follow-up analysis following a significant F-value.

In addition to the analysis of variance that was performed on the walking and performance data, a standard independent t-test for the difference between two sample means was used to examine the anthropometry data. This was used when comparing the anthropometric characteristics of the sample subjects with those of the Army population as represented by the 1966 and 1977 anthropometric surveys for Army men and women (ref. 2 and 3). It was felt that a t-test for the difference between two sample means was more appropriate than a t-test for the difference between sample and population means since the military data truly represent a large sample and not a population.

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[5] Games, P.A., G.S. Gray, W.L. Herron, A. Pentz, and G.F. Pitz. Analysis of Variance with Repeated Measures. University Park, Pennsylvania: The Pennsylvania State University Computation Center, June 1979.

RESULTS

Anthropometry

Measures for fifteen anthropometric variables were taken on each subject in order to provide a description of the body size and dimensions of the sample subjects and to allow for a comparison of the sample anthropometric characteristics with those of the military population. An independent t-test for the difference between sample means was used to indicate how the sample subjects compared with large samples of male and female Army personnel as represented in the 1966 and 1977 anthropometry reports (ref. 2 and 3). The means and standard deviations for each of the fifteen anthropometric variables for the male subjects of this study and for Army personnel are contained in Table 1. In addition, the results of the t-test for each variable are contained in the same table. Significant differences between the sample and Army personnel means are denoted by an asterisk (*). The 0.05 level of significance was used to determine the presence or absence of significant differences. The means, standard deviations, and t-test results for the females are contained in Table 2.

Table 1

Anthropometric Characteristics of the Men

Variable	Project $\bar{X}$	Sample S.D.	Army $\bar{X}$	Personnel S.D.	t
Stature (cm)	174.0	7.0	174.5	6.6	0.34
Body Mass (kg)	73.0	9.1	72.2	10.6	0.28
Waist Back Length (cm)	44.2	2.4	45.0	3.4	1.38
Cervicale Height (cm)	148.3	6.5	149.6	6.3	0.82
Shoulder Height (cm)	143.7	6.5	143.7	6.2	0.02
Crotch Height (cm)	80.2	3.7	83.9	4.7	3.34*
Waist Height (cm)	104.0	4.4	106.3	5.4	1.77
Buttock Height (cm)	89.6	4.6	(no	data)	--
Sitting Height (cm)	90.7	3.9	90.7	3.7	0.03
Shoulder Circumference (cm)	115.9	5.9	113.2	6.4	1.77
Chest Circumference at Scye (cm)	97.9	7.2	(no	data)	--
Chest Circumference (cm)	95.1	5.4	93.8	6.7	0.79
Waist Circumference (cm)	79.9	6.2	80.3	8.2	0.21
Hip Circumference (cm)	96.6	5.1	94.2	6.2	1.60
Interscye Breadth (cm)	39.6	2.2	39.1	3.2	0.62

* $P < 0.05$

Table 2

Anthropometric Characteristics of the Women

Variable	Project $\bar{X}$	Sample S.D.	Army $\bar{X}$	Personnel S.D.	*t*
Stature (cm)	164.5	5.9	163.0	6.5	0.93
Body Mass (kg)	59.9	5.5	60.0	8.7	0.05
Waist Back Length (cm)	40.3	2.2	40.9	2.6	0.83
Cervicale Height (cm)	141.1	7.2	140.3	6.0	0.50
Shoulder Height (cm)	136.5	5.8	133.5	6.0	2.01*
Crotch Height (cm)	77.2	3.8	76.4	4.4	0.79
Waist Height (cm)	101.7	4.6	101.4	5.2	0.25
Buttock Height (cm)	86.3	4.1	83.8	4.7	2.14*
Sitting Height (cm)	86.4	2.9	85.1	3.6	1.44
Shoulder Circumference (cm)	101.3	5.8	100.4	5.5	0.69
Chest Circumference at Scye (cm)	85.5	4.6	85.6	5.2	0.08
Bust Circumference (cm)	88.1	5.1	88.2	6.4	0.08
Waist Circumference (cm)	75.4	5.2	76.2	7.9	0.21
Hip Circumference (cm)	96.2	5.2	95.5	6.4	0.45
Interscye Breadth (cm)	35.0	3.3	37.9	2.4	4.75*

* $P < 0.05$

For the men, measures for two of the fifteen anthropometric variables for the sample could not be compared with published data on Army men since the variables buttock height and chest circumference at scye were not included in the 1966 anthropometry report for men (ref. 2). Of the thirteen variables for which comparisons could be made, only one showed a significant *t*-value for the difference between sample and population means. The statistical results demonstrated that the sample men had a significantly lower value for crotch height ($\bar{X}$ diff. = 3.7 cm) than the military men. A close examination of the sample and Army mean and standard deviation values demonstrated the sample subjects were quite similar in body size to the Army men. Consequently, it can be concluded that the sample subjects were highly representative of the population to which results were to be extrapolated.

For the women, it was possible to statistically compare sample data with data for Army women as represented in the 1977 anthropometry report on women (ref. 3) for all fifteen variables considered in this study.. Although the measurement protocal for waist height and waist back length differed slightly from that of the 1977 study, this was considered to be of minor importance. Significant differences were found for only three of these variables. The results showed that the sample women had significantly greater shoulder heights ($\bar{X}$ diff. = 3.0 cm) and buttock heights ($\bar{X}$ diff. = 2.5 cm) and smaller interscye breadth measures ($\bar{X}$ diff. = 2.9 cm) than the military women. In addition, the mean values indicated that the sample subjects were slightly taller than the Army subjects, although this difference was not significant, and the two groups were nearly identical in body mass. In general, however, the means and standard deviations for the fifteen variables for the two groups were quite similar. Therefore, it was concluded that the female subjects of the sample were representative of the population of Army women even though some minor differences existed.

Physical Performance Tests

The effects of four factors--gender, frame length, load, and participation time--on combative movement performance and treadmill walking were examined in this study. It was previously noted that certain frame length and load conditions were common to both the men and women and others were different. Consequently, two separate, three-factor ANOVA designs were used to statistically analyze the performance test and walking data. The first of these two designs considered the effects of frame length, load, and participation time on performance variables for the men and women separately. The second design considered the effects of gender, frame length, and participation time for the conditions common to both the men and women.

The statistical results and appropriate mean values for the two performance tests and the six variables used to quantify walking patterns are presented in tabular form in the discussion that follows. In all of the tables presenting statistical results, mean values which are not connected by a solid vertical or horizontal line are significantly different at the 0.05 level. Those means which are connected are not significantly different. Because of the complexity of the statistical analysis and the large number of mean values generated in this study, only the main means for the factors under investigation and those mean values considered in the follow up analyses are presented in the following discussion. Appendix B contains a more complete summary of the mean values calculated from the raw data including cell means. All of the ANOVA summary tables are contained in Appendix C.

Agility Run. The results of the ANOVA design in which the effects of frame length, load, and participation time on men's agility run performance were evaluated showed that the three-factor interaction and all two-factor interactions were not significant. In addition, the main effects for frame length and participation time also were not significant. Table 3 contains the main mean values for these two factors and also for load. While the main effect for frame length was nonsignificant, the mean values indicate that performance improved in a nearly linear fashion as frame length was increased from 18 to 24 inches. This suggests that there may be a trend toward better agility run performance for the men under the longer frame length conditions. The mean values for participation time, on the other hand, were nearly identical to one another which demonstrates that the men showed no decrement in agility run performance after approximately 50 minutes of continuous activity. The only significant F-value in this ANOVA for men's agility run performance was for the main effect of load. The results demonstrated that, as load was increased from 26 to 40 kg, agility run performance declined by approximately 9%. This result is consistent with previous research on load carrying behavior (ref. 4).

Table 3

Mean Agility Run Performance (sec) for Frame Length, Load, and Participation Time

Variable	Men N	Men $\bar{X}$	Women N	Women $\bar{X}$
Frame Length (in.)				
16	-	-	96	9.47
18	102	8.42	96	9.44
20	102	8.37	96	9.22
22	102	8.32	96	9.33
24	102	8.26	-	-
Load (kg)				
26	204	7.98	192	9.12
33	-	-	192	9.61
40	204	8.70	-	-
Participation Time (min.)				
0	136	8.35	128	9.41
25	136	8.34	128	9.37
50	136	8.34	128	9.30

Table 3 also contains the main mean values for frame length, load, and participation time for the women. The results of the three-factor ANOVA design for the women's data were quite similar to those found for the men except that the three-factor interaction was significant. All two-factor interactions were not significant. Consequently, attention was turned to the main effects. Just as for the men, the frame length and participation time main effects were not significant. There were, however, some interesting trends in the mean values for these two variables. For frame length, agility run performance improved as frame length was increased from 16 to 20 inches but then declined as the length was further increased to 22 inches. This suggests that there was a tendency for the current standard frame size of 20 inches to be the best for the women with respect to agility run performance. The mean values for participation time demonstrated an unusual and unexpected pattern. Rather than performance decreasing over time during the 55 minute test protocol, agility run times for the females actually improved from the initiation of the test session until the end of the session. This meant that nearly an hour of mild physical activity appeared to have no detrimental effect on agility run performance. The reasons for the improvement in performance are unclear although warmup and/or learning effects are possible explanations for this trend. The only significant result for the women was found for the main effect of load. The results demonstrated that performance was significantly poorer under the heavier of the two load conditions. This difference was approximately 5% for the 7-kg increase in load, which was consistent with the decline in agility run performance with load increases found by Nelson and Martin (ref. 4).

In the second of the two ANOVA designs, the effects of gender, frame length, and participation time on agility run performance were considered for the common frame lengths (18, 20, and 22 inches) and load (26 kg) for the men and women. Table 4 contains the main means for the three factors. The absence of lines connecting mean values in this table should not be confused with the presence of significant differences for this design. The ANOVA results indicated that the three-factor interaction was significant. Consequently, the design was split on the gender factor and the data were reanalyzed in two separate two-factor designs, one for the men and one for the women. The data in Table 4 are presented simply for informational purposes. Because of an a priori interest in the main effects, however, it should be noted that the gender and participation time _F_-values were significant. The performance of the men was better than that of the women and performance improved between the first and second data collection periods. These results are less meaningful, however, because of the significant interaction.

Table 4

Mean Agility Run Performance (sec) for Gender, Frame Length, and Participation Time

Variable	N	$\bar{X}$
Gender		
Men	153	7.98
Women	144	9.05
Frame Length (in.)		
18	99	8.58
20	99	8.43
22	99	8.49
Participation Time (min.)		
0	99	8.56
25	99	8.48
50	99	8.47

The mean values for the two-factor ANOVA of frame length and participation time for the men are contained in Table 5. The results of the statistical analysis indicated that the interaction and both main effects were not significant. The trends present in the men's data, however, are consistent with those already noted for agility run performance. That is, there was a tendency for performance to be better under longer frame length conditions and there was a slight improvement in performance over time.

Table 5

Mean Agility Run Performance (sec) for Frame Length and Participation Time for the Men

Participation Time (min.)	Frame Length (in.) 18	20	22	Time $\bar{X}$
0	8.09	8.01	8.00	8.03
25	7.97	7.91	7.99	7.96
50	8.00	7.99	7.90	7.96
Frame $\bar{X}$	8.02	7.97	7.96	

Table 6 contains the mean values and summarizes the statistical results for the two-factor ANOVA for the women's data. The results demonstrated that the frame length-participation time interaction was significant. The results also showed that both main effects were not significant. Because of the significant interaction, the follow-up analysis focused on the cell means. The cell means are also plotted in Figure 2 to graphically display the interaction. The results of the follow-up analysis indicated that there were few significant differences among the mean values. There was a significant difference between the 18- and 20-inch frames but only after 50 minutes of activity. The results showed that performance under the 20-inch frame was better than that for the 18-inch frame. In addition, the results indicated that there was a significant improvement in performance between 0 and 25 minutes of participation, but only for the 20-inch frame condition.

There were two interesting trends which are clearly demonstrated in Figure 2. It was previously noted in the discussion of the women's results for the ANOVA examining frame length, load, and participation time that there was a tendency for improved performance as participation time increased. Figure 2 shows that the response to increased participation time was similar for the 20- and 22-inch frames, but considerably different for the 18-inch frame. While performance improved slightly over time under the 20- and 22-inch frames, performance declined under the 18-inch frame. As was previously noted, these changes were not significant except for the 20-inch frame. In addition, Figure 2 demonstrates that, when activity was first initiated, there was very little difference between performance under the three frame conditions. When participation continued, however, the differences between frames increased such that the greatest differences were present after 50 minutes of activity. These data once again suggest that the 20 inch frame was most advantageous for the females, particularly as activity continued over time.

Table 6

Mean Agility Run Performance (sec) for Frame Length and Participation Time for the Women

Participation Time (min.)	Frame Length (in.) 18	20	22	Time $\bar{X}$
0	9.11	9.11	9.16	9.13
25	9.20	8.87	9.02	9.03
50	9.22	8.80	9.00	9.01
Frame $\bar{X}$	9.18	8.92	9.06	

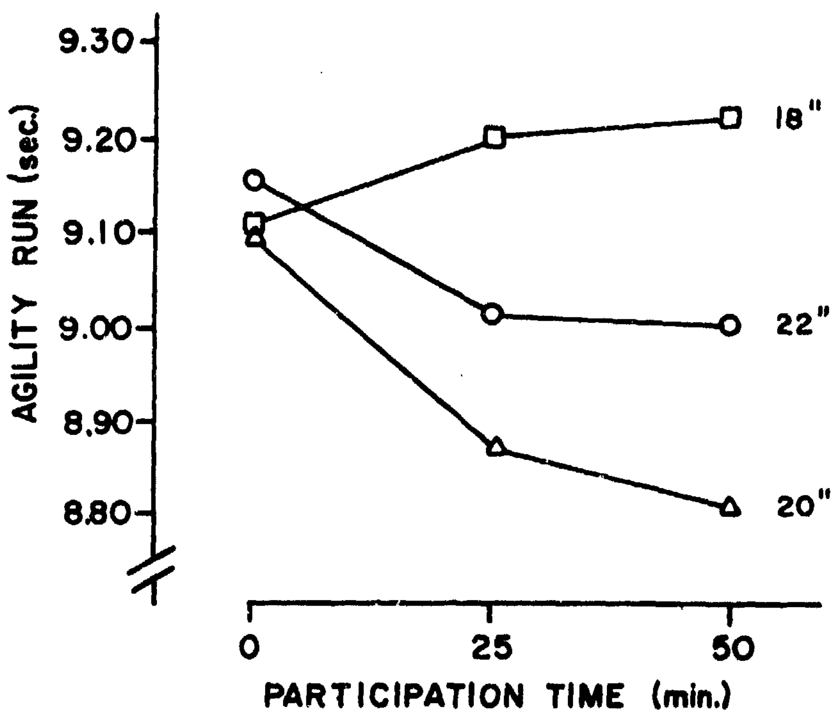

Figure 2. Plot of the cell means for women's agility run performance demonstrating the frame length-participation time interaction.

Ladder Climb. The ladder climb data were analyzed in a manner identical to that done for the agility run. The results of the three-factor ANOVA design in which frame length, load, and participation time were examined for the men demonstrated that only the load x time interaction was significant. In addition, there was a nonsignificant effect due to frame length. Significant F-values were found for the main effects of load and participation time. Table 7 contains the mean values for the three main effects and demonstrates that ladder climb performance was considerably poorer under the 40-kg load condition than the 26-kg load. In addition, performance showed a significant improvement as the time of participation increased, which was once again contrary to what was expected, but nevertheless was consistent with the agility run results.

Table 7

Mean Ladder Climb Performance (sec) for Frame Length, Load, and Participation Time

Variable	Men N	Men $\bar{X}$	Women N	Women $\bar{X}$
Frame Length (in.)				
16	-	-	96	5.50
18	102	3.26	96	5.67
20	102	3.20	96	5.46
22	102	3.20	96	5.88
24	102	3.18	-	-
Load (kg)				
26	204	2.84	192	5.00
33	-	-	192	6.26
40	204	3.58	-	-
Participation Time (min)				
0	136	3.30	128	5.96
25	136	3.21	128	5.61
50	136	3.12	128	5.32

Table 7 also contains the mean values for frame length, load, and participation time for the women's ladder climb data. The results of the ANOVA design in which these three factors were considered indicated that there were no significant interactions and that the main effect of frame length was also nonsignificant. Only the load and participation time main effects were significant. The trends found for these two factors were nearly identical to those found for the men. Increasing the load from 26 to 33 kg resulted in a decrease in performance. In addition, increasing the time of participation from 0 to 50 minutes resulted in improved ladder climb performance.

Even though the frame-load interaction was nonsignificant for the women, there was an interesting trend found in the mean data which is worth noting. Figure 3 is a plot of the frame-load surface means for women's ladder climb performance and demonstrates this trend. Under the lighter of the two load conditions, the women's performances were fairly similar for the four frame length conditions. There was, however, a tendency for performance to be somewhat better as frame length increased from 16 to 22 inches. An interesting reversal occurred when the subjects performed under the heavier load condition. Not only did performance decline considerably for all frame lengths as load was increased, but also the differences between performances under the four frame conditions increased under the heavier load. However, the most interesting trend is that the shortest frame resulted in the best performance and the longest frame in the worst performance under the heavier load. This was exactly opposite to that found for the lighter load. While the women demonstrated these patterns, the men showed no such trend toward a frame-load interaction. In fact, the responses under the different frame conditions as load was increased were nearly identical to one another for the men.

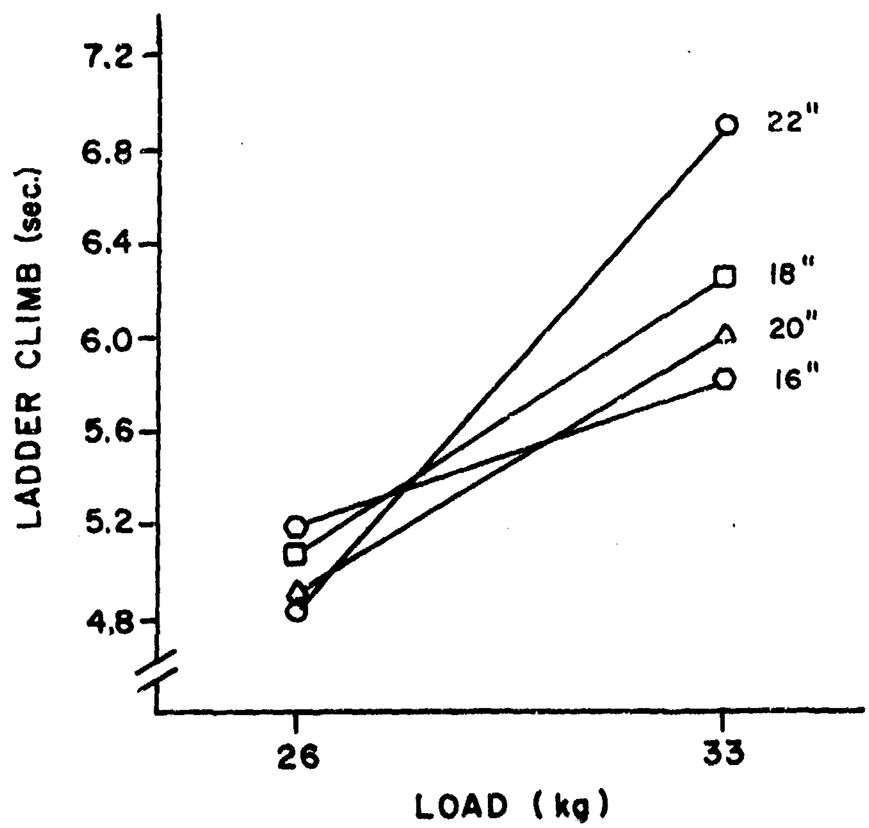

Figure 3. Plot of the frame length-load surface means for ladder climb performance of the women.

The results of the three-factor ANOVA of gender, frame length, and participation time for ladder climb performance demonstrated the three-factor interaction was not significant. In addition, the frame length-participation time and gender-frame length interactions were also nonsignificant along with the frame length main effect. However, the gender-participation time interaction and the main effects for gender and participation time were all significant. Table 8 contains the main mean values for the three factors and Table 9 contains the gender-participation time surface means and the results of the follow-up analysis on these means. The results of the follow-up indicated that the men's and women's performances were significantly different from one another at all three sample times during the test session. In addition, the results indicated that the performance at time 0 for both the men and women was significantly different from performances at 25 and 50 minutes. The interaction is further demonstrated in Figure 4 which graphically depicts the gender-participation time interaction. The graph shows that both men's and women's performances improved as participation continued over time but that the women showed a greater change than the men.

Table 8

Mean Ladder Climb Performance (sec) for Gender, Frame Length, and Participation Time

Variable	N	$\bar{X}$
Gender		
Men	153	2.86
Women	144	4.94
Frame Length (in.)		
18	99	3.97
20	99	3.82
22	99	3.82
Participation Time (min)		
0	99	4.11
25	99	3.82
50	99	3.67

Table 9

Gender-Participation Time Surface Mean Values
for Ladder Climb Performance (sec)

	Participation Time (min)			
Gender	0	25	50	Gender $\overline{X}$
Men	3.00	2.83	2.74	2.86
Women	5.29	4.88	4.66	4.94
Participation Time $\overline{X}$	4.11	3.82	3.67	

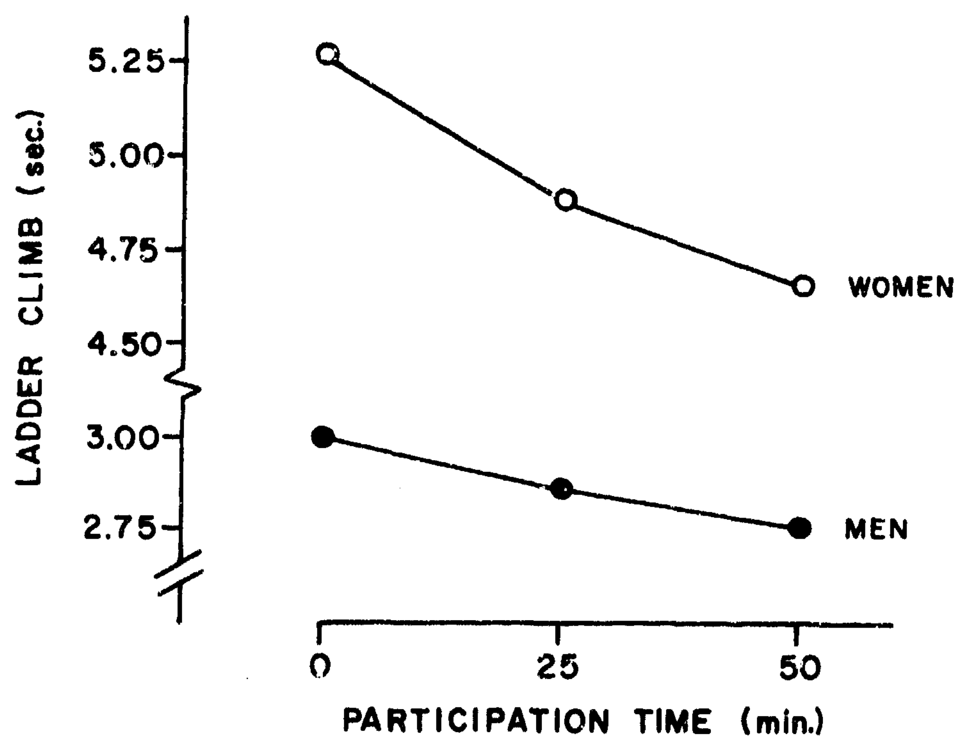

Figure 4. Gender-participation time interaction for ladder climb.

Analysis of Treadmill Walking

As was previously noted, the statistical designs used to analyze the walking data were nearly identical to those used to examine the performance data. The only difference between the two was in the number of levels of the participation time factor. Filming of treadmill walking occurred twice during each test session. Consequently, there were only two levels of this factor for the walking analysis as compared to three levels for the performance tests. Otherwise the ANOVA designs were the same. The effects of frame length, load, and participation time on the walking variables were examined for the men and women separately. The effects of gender, frame length, and participation time were considered in the second ANOVA design for those conditions common to both the men and women.

Stride Length. The results of the three-factor ANOVA design for the men's stride length data indicated that all interactions were nonsignificant and that the frame length main effect was also nonsignificant. The main effects for load and participation time, however, were both significant. Table 10 contains the mean values for frame length, load, and participation time. The results showed that an increase in load from 26 to 40 kg produced a decrease in stride length. In addition, the increased time of participation also produced a decrease in stride length. These changes were quite small for both main effects.

The results for the women's stride length data indicated that the only significant F-value was for the main effect of load. All interactions and the frame length and participation time main effects were nonsignificant. The results for load showed that the women decreased their stride lengths as load was increased from 26 to 33 kg. Just as for the men, however, this change in stride length was quite small. The women also showed some tendency toward a frame length-load interaction. This situation is plotted in Figure 5 and indicates that there were greater adjustments in stride length under the 33-kg load than the 26-kg load. Once again, however, the changes were considered to be quite small.

The results of the ANOVA design in which the effects of gender, frame length, and participation time on stride length were considered showed that the three-factor interaction and the gender-frame length and frame length-participation time interactions were not significant. In addition, the frame length and participation time main effects also were not significant. The only significant results were found for the gender-participation time interaction and the gender main effect. The main effect mean values can be found in Table 11, whereas the gender-participation time surface means are contained in Table 12 and are presented graphically in Figure 6. The results of the follow-up analysis on means depicted in Figure 6 indicated that the men had significantly greater stride lengths than the women both early and late in the test session. In addition, the men showed a significant decrease in stride length over time, whereas the women showed a small but nonsignificant increase in stride length.

Table 10

Mean Stride Length Values (m) for Frame Length, Load, and Participation Time

Variable	Men N	Men $\overline{X}$	Women N	Women $\overline{X}$
Frame Length (in)				
16	-	-	64	0.759
18	68	0.796	64	0.757
20	68	0.804	64	0.754
22	68	0.799	64	0.759
24	68	0.801	-	-
Load (kg)				
26	136	0.805	128	0.762
33	-	-	128	0.753
40	136	0.795	-	-
Participation Time (min)				
5	136	0.803	128	0.757
45	136	0.797	128	0.758

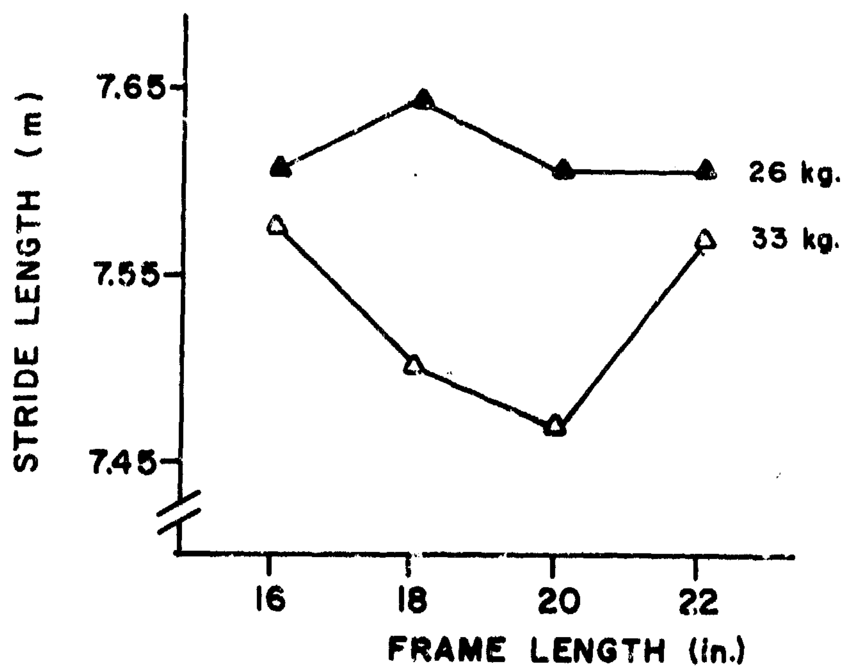

Figure 5. Plot of the women's frame length-load surface means for stride length.

Table 11

Mean Stride Length Values (m) for Gender, Frame Length, and Participation Time

Variable	N	$\bar{X}$
Gender		
Men	102	0.805
Women	96	0.762
Frame Length (in.)		
18	66	0.783
20	66	0.785
22	66	0.785
Participation Time (min)		
5	99	0.786
45	99	0.782

Table 12

Gender-Participation Time Surface Mean Values for Stride Length (m)

	Participation Time (min)		
Gender	5	45	Gender $\bar{X}$
Men	0.808	0.801	0.805
Women	0.761	0.763	0.762
Participation Time $\bar{X}$	0.786	0.782	

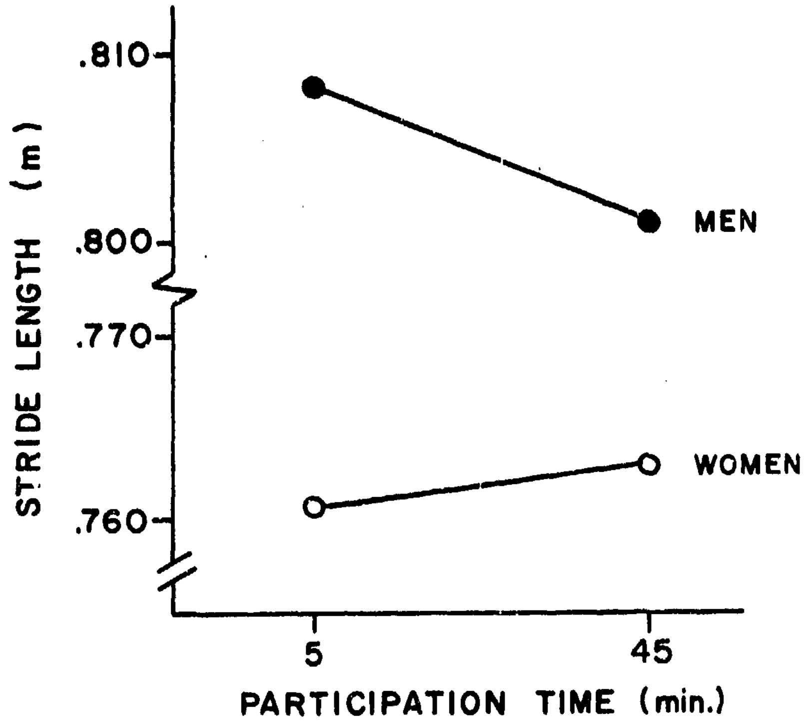

Figure 6. Gender-participation time interaction for stride length.

Stride Rate. Because stride velocity was held constant by using the treadmill for the examination of walking patterns, one could expect the statistical results for stride rate to be nearly identical to those for stride length. This, in fact, was the result of the analyses of the stride rate data. For the men's data, only the load and participation time main effects were statistically significant and, for the women, only the load main effect was significant. The mean values for the men and women are found in Table 13. They indicate that increased load produced an increased rate of striding for both sexes and that increased time of participation resulted in an increased stride rate for the men.

The results of the ANOVA considering the effects of gender, frame length, and participation time on stride rate again were identical to those found for stride length. There was a significant gender-participation time interaction and a gender main effect. Table 14 contains the main mean values for this analysis. The results demonstrated that the average stride rate for the men was less than that for the women. In addition, the follow-up analysis on the gender-participation time surface means demonstrated the men and women differed significantly at both sample times and that the men significantly increased their stride rate over time. These surface means are contained in Table 15 and the interaction is shown graphically in Figure 7. Just as for stride length, those changes in stride rate which were found to be significant were nevertheless quite small.

Table 13

Mean Stride Rate Values (str/sec) for Frame Length, Load, and Participation Time

Variable	Men N	Men $\bar{X}$	Women N	Women $\bar{X}$
Frame Length (in)				
16	-	-	64	2.06
18	68	1.97	64	2.07
20	68	1.95	64	2.08
22	68	1.96	64	2.07
24	68	1.96	-	-
Load (kg)				
26	136	1.95	128	2.06
33	-	-	128	2.08
40	136	1.97	-	-
Participation Time (min)				
5	136	1.95	128	2.07
45	136	1.97	128	2.07

Table 14

Mean Stride Rate Values (str/sec) for Gender, Frame Length, and Participation Time

Variable	N	$\bar{X}$
Gender		
Men	102	1.95
Women	96	2.06
Frame Length (in.)		
18	66	2.00
20	66	2.00
22	66	2.00
Participation Time (min)		
5	99	2.00
45	99	2.01

Table 15

Gender-Participation Time Surface Means
for Stride Rate (str/sec)

Gender	Participation Time (min) 5	45	Gender $\bar{X}$
Men	1.939	1.959	1.949
Women	2.058	2.055	2.056
Participation Time $\bar{X}$	1.997	2.005	

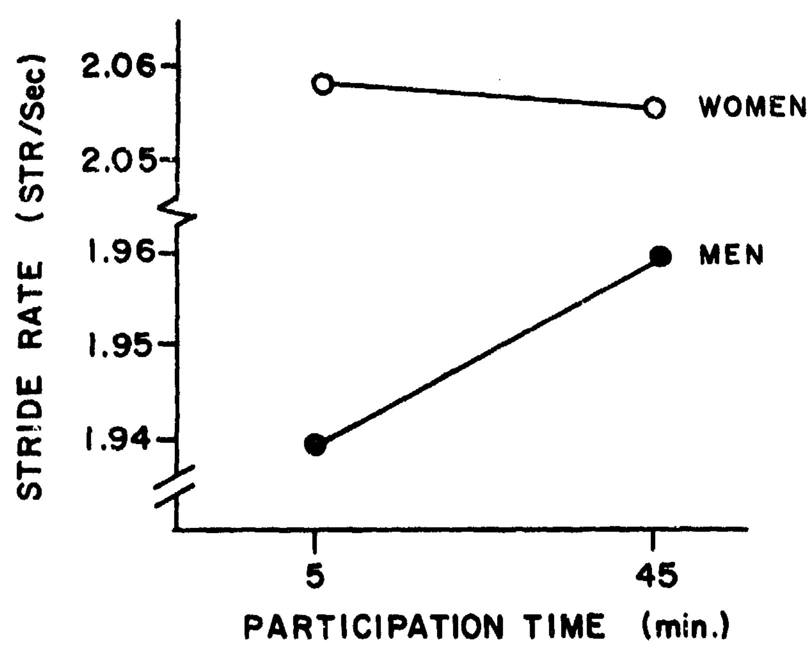

Figure 7. Gender-participation time interaction for stride rate.

Single Leg Contact Time. Table 16 contains the mean values for frame length, load, and participation time for the men and women. The ANOVA results for the men's data demonstrated that only the load main effect was significant. As load was increased from 26 to 40 kg, the men tended to increase their times for single leg contact. This increase was a modest 6 msec. There were also some minor adjustments in contact time as frame length was changed, but these adjustments were small and did not demonstrate a consistent trend. The ANOVA results for the women's data indicated that there were no significant results. The women also demonstrated some minor adjustments in contact time as frame length varied, but again there was no consistent trend. For the ANOVA design considering gender, frame length, and participation time effects, only the gender main effect was significant. The results indicated that the men had greater single leg contact times than the women. This difference between the men and women was considerably greater than the modest adjustments due to varying frame length, load, and participation time. Table 17 contains the mean values for this design.

Table 16

Mean Single Leg Contact Times (msec) for Frame Length, Load, and Participation Time

Variable	Men N	Men $\bar{X}$	Women N	Women $\bar{X}$
Frame Length (in)				
16	-	-	64	625
18	68	656	64	625
20	68	661	64	621
22	68	657	64	626
24	68	662	-	-
Load (kg)				
26	136	656	128	624
33	-	-	128	625
40	136	662	-	-
Participation Time (min)				
5	136	660	128	623
45	136	658	128	625

Table 17

Mean Single Leg Contact Times (msec) for Gender, Frame Length, and Participation Time

Variable	N	$\overline{X}$
Gender		
Men	102	656
Women	96	624
Frame Length (in.)		
18	66	640
20	66	640
22	66	642
Participation Time (min)		
5	99	641
45	99	640

Swing Time. Table 18 contains the mean values for swing time for the men and women. The results of the statistical analysis considering the effects of frame length, load, and participation time on the men's data indicated that all interactions and the frame length main effect were not significant. Only the load and participation time main effects were statistically significant. Both increased load and increased participation time produced decreases in swing time although the relative effect of load on swing time was considerably greater than that attributed to participation time. Neither change, however, can be considered to be large from a practical standpoint. For the women, the ANOVA results demonstrated that only the load main effect was significant. The trend was the same as that found for the men in that swing time decreased as load was increased. The results for the remaining ANOVA design considering those conditions common to the men and women showed that all interactions and the frame length and participation time main effects were not significant. For this analysis, only the gender main effect was significant with the males demonstrating greater swing times than the females. Table 19 contains the mean values for this design.

Table 18

Mean Swing Times (msec) for Frame Length, Load, and Participation Time

Variable	Men N	Men $\overline{X}$	Women N	Women $\overline{X}$
Frame Length (in)				
16	-	-	64	345
18	68	361	64	342
20	68	366	64	342
22	68	363	64	343
24	68	362	-	-
Load (kg)				
26	136	372	128	349
33	-	-	128	337
40	136	354	-	-
Participation Time (min)				
5	136	365	128	343
45	136	361	128	343

Table 19

Mean Swing Times (msec) for Gender, Frame Length, and Participation Time

Variable	N	$\overline{X}$
Gender		
Men	102	372
Women	96	349
Frame Length (in.)		
18	66	361
20	66	363
22	66	361
Participation Time (min)		
5	99	362
45	99	360

Double Support Time. The mean values for double support time for the men and women are shown in Table 20. The ANOVA results for the men's and women's data were quite similar. For both, all interactions and the frame length and participation time main effects were not significant. Only the load main effect was significant. Both the men and women increased double support times as load was increased. Although not significant, there was a trend towards a frame length-participation time interaction for the women. Figure 8 is a plot of the data demonstrating this trend. The figure shows that double support times changed very little over time for the two longest frames, 20 and 22 inches, used by the women. On the other hand, the double support times under the 16- and 18-inch frame length conditions increased over time. This suggests that, with respect to double support time, there was less modification in the women's walking patterns over time when using the longer frame lengths. As has been noted for other variables, however, the observed changes were small.

For the final ANOVA design in which the effects of gender, frame length, and participation time on double support time were considered, there were no significant results. Not even the gender main effect was significant which was somewhat surprising since the men and women demonstrated considerably different values for all other variables discussed thus far. Table 21 contains the gender, frame length, and participation time mean values for this design.

Table 20

Mean Double Support Times (msec) for Frame Length, Load, and Participation Time

Variable	Men N	Men $\bar{X}$	Women N	Women $\bar{X}$
Frame Length (in.)				
16	-	-	64	142
18	68	148	64	143
20	68	148	64	141
22	68	147	64	142
24	68	151	-	-
Load (kg)				
26	136	142	128	139
33	-	-	128	145
40	136	155	-	-
Participation Time (min)				
5	136	148	128	141
45	136	149	128	143

Table 21

Mean Double Support Times (msec) for Gender, Frame Length, and Participation Time

Variable	N	$\bar{X}$
Gender		
Men	102	142
Women	96	139
Frame Length (in.)		
18	66	141
20	66	140
22	66	140
Participation Time (min)		
5	99	140
45	99	140

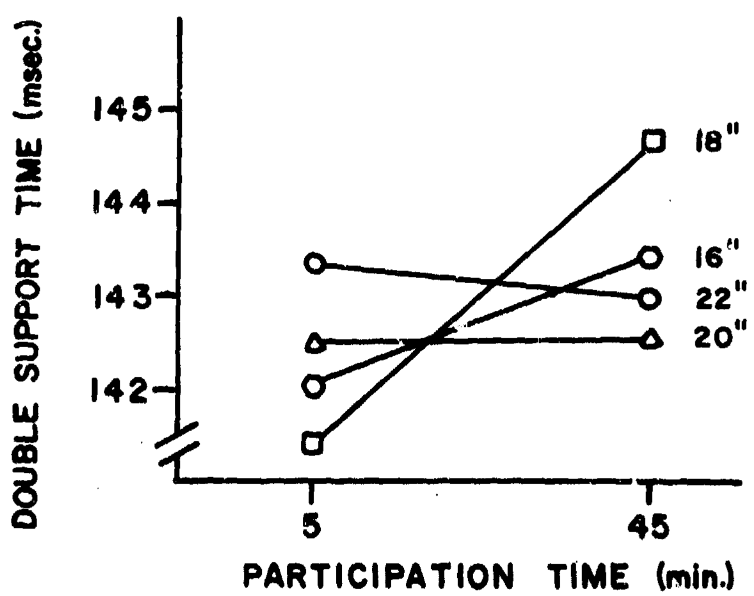

Figure 8. Plot of the women's frame length-participation time surface means for double support time.

Trunk Angle. The mean values for the main effects of frame length, load, and participation time for trunk angle are contained in Table 22. The ANOVA results for the men's data indicated that the frame length-participation time interaction and the frame length and load main effects were significant, whereas all other *F*-values were not. Table 23 contains the surface means for frame length and participation time averaged over load and indicates the results of the follow-up analysis of these means. These same means are plotted in Figure 9 to further demonstrate the nature of the interaction. The follow-up results showed there were few significant contrasts. Only for the 18-inch frame length was there a significant change in trunk angle over time. The results indicated trunk angle was slightly less at 45 minutes than at 5 minutes. In addition, the results generally indicated that the trunk angles under the 18-inch condition were significantly less than those under the 20-, 22-, and 24-inch conditions at both the 5- and 45-minute sampling periods. All of these differences between any two of these means were less than three degrees. Consequently, the importance of these differences is questionable.

Table 22

Mean Trunk Angle Values (deg) for Frame Length, Load, and Participation Time

Variable	Men N	Men $\bar{X}$	Women N	Women $\bar{X}$
Frame Length (in)				
16	-	-	64	81.5
18	68	81.1	64	80.7
20	68	83.7	64	81.9
22	68	82.6	64	79.5
24	68	83.2	-	-
Load (kg)				
26	136	85.4	128	83.0
33	-	-	128	78.8
40	136	79.9	-	-
Participation Time (min)				
5	136	82.7	128	81.1
45	136	82.6	128	80.8

Table 23

Frame Length-Participation Time Surface Means for the Men for Trunk Angle (deg)

Participation Time	18	20	22	24	Time $\bar{X}$
	Frame Length (in.)				
5	81.6	83.4	82.5	83.4	82.7
45	80.6	83.9	82.8	83.0	82.6
Frame Length $\bar{X}$	81.1	83.7	82.6	83.2	

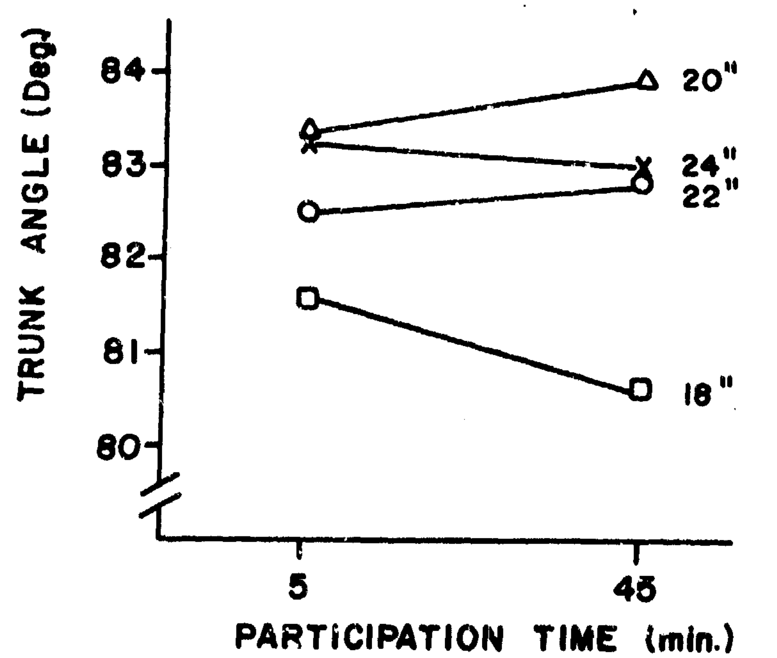

Figure 9. Frame length-participation time interaction for trunk angle for the men.

The ANOVA results for the women's data indicated that all interactions and the participation time main effect were not significant. The frame length and load main effects, however, were significant. The results of the follow-up analysis on the frame length main means are shown in Table 22 and demonstrate that the trunk angles under the 16-, 18-, and 20-inch conditions were not significantly different from another. The smallest mean trunk angle was found for the 22-inch frame condition, but this value was significantly different only from the values for the 16- and 20-inch conditions. While there were significant differences between certain conditions, these differences were once again quite small. The effect of load on trunk angle was somewhat more notable. The data indicated that, as load was increased, the trunk was inclined more forward to counteract the load.

For the final ANOVA design in which effects of gender, frame length, and participation time on trunk angle were considered, the results showed that the three-factor interaction, the gender-participation time interaction, and the participation time main effect were not significant. On the other hand, the gender-frame length and frame length-participation time interactions and the gender and frame length main effects were all significant. Table 24 contains the main means for this design. Table 25 contains the gender-frame length surface means which were averaged over the participation time factor and also exhibits the results of the follow-up analysis on these means. The results revealed that the men had significantly greater trunk angles under the 20- and 22-inch frame length conditions than the women. In addition, the men showed no significant changes in trunk angle as frame length was changed, whereas the women displayed significantly smaller trunk angles under the 22-inch condition than under the 20-inch condition. The mean values for both the men and women are also plotted in Figure 10 which further highlights the nature of the gender-frame length interaction. Because of the interaction, the significance of the gender and frame length main effects is less meaningful, but nevertheless the mean values for these factors are also shown in Table 25.

Table 26 contains the frame length-participation time surface means for trunk angle and the results of the follow-up analysis on these means. The results showed there was a significant change in trunk angle over time under the 18-inch frame condition only. Trunk angle was slightly smaller at the 45-minute point relative to the value at five minutes. In addition, the results showed the mean trunk angles under the 20-inch frame length were significantly greater than those values under the 18- and 22-inch frames at both the five- and 45-minute sampling periods. Figure 11 is a plot of the frame length-participation time means which graphically depicts the interaction between these variables. The differences between these means were all quite small even though some differences were statistically significant.

Table 24

Mean Trunk Angle Values (deg) for
Gender, Frame Length, and Participation Time

Variable	N	$\overline{X}$
Gender		
Men	102	85.2
Women	96	82.7
Frame Length (in.)		
18	66	83.7
20	66	84.8
22	66	83.6
Participation Time (min)		
5	99	84.0
45	99	84.0

Table 25

Gender-Frame Length Surface Means for
Trunk Angle (deg)

Gender	Frame Length (in.) 18	20	22	Gender $\overline{X}$
Men	84.2	85.9	85.6	85.2
Women	83.1	83.6	81.4	82.7
Frame Length $\overline{X}$	83.7	84.8	83.6	

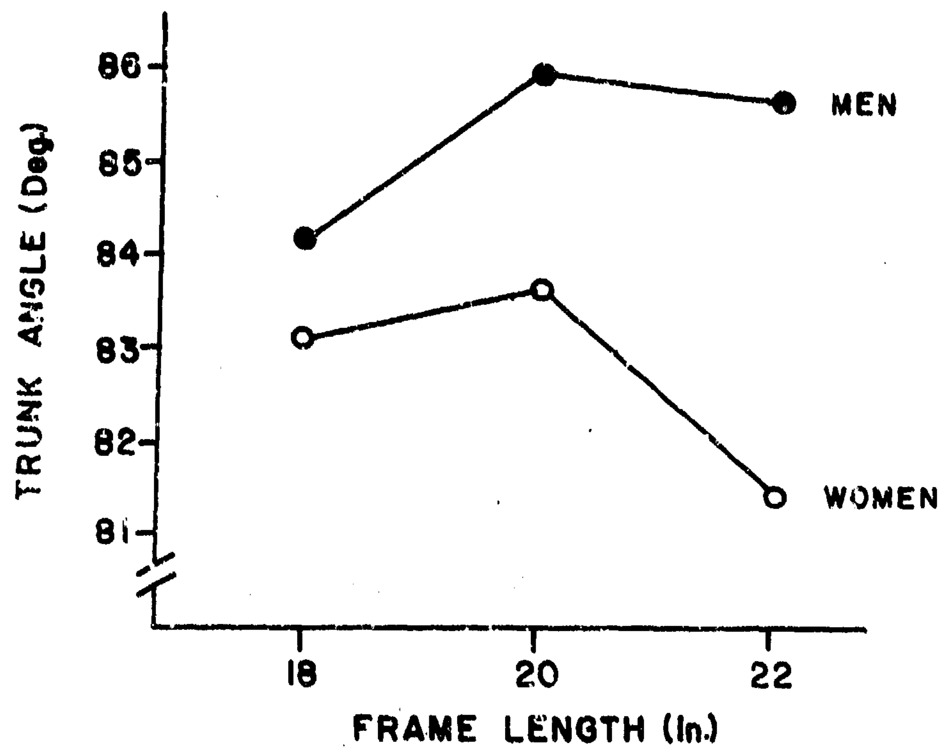

Figure 10. Gender-frame length interaction for trunk angle.

Table 26

Frame Length-Participation Time Surface Means for Trunk Angle (deg)

Participation Time (min)	Frame Length (in.) 18	20	22	Time $\bar{X}$
5	83.9	84.5	83.5	84.0
45	83.4	85.0	83.6	84.0
Frame Length $\bar{X}$	83.7	84.8	83.6	

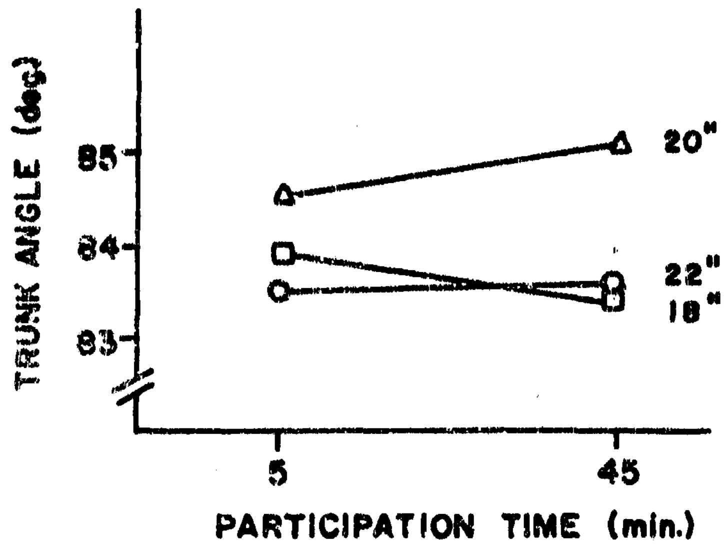

Figure 11. Frame length-participation time interaction for trunk angle averaged over gender.

Qualitative Analysis of Personalized Frame Length

It was noted earlier in this report that previous research by Martin et al. (ref. 1) had examined the influence of frame length on performance by assigning frame length conditions to each subject based on their waist back length measure. In this way, the frame conditions were normalized to body size. In the present study, the frame length conditions were not tied to body size but rather the same absolute frame sizes were used by all subjects. This was deemed most appropriate to adequately determine whether the current standard frame length of 20 inches (50.8 cm) is the most suitable length for all subjects regardless of body structure. Nevertheless, it was still of interest to consider performance under different frame conditions when normalized to the body size. Two approaches were used in this study in an effort to examine the relationship between normalized frame length and performance.

The first of these two approaches involved predicting performance scores for each subject for a personalized (P) frame length. This personalized frame length was calculated by adding 1.25 inches (3.18 cm) to the waist back length measure. In addition, performance was predicted for a frame which was the personalized length plus two inches (5.1 cm) (P+2). This was the same approach utilized by Martin et al. (ref. 1) in their examination of frame length effects. Appendix D contains the waist back length and the personalized frame length measures for the subjects of this study. Predicted performance scores for each subject under these two conditions (P and P+2) were generated for the agility run and ladder climb by linear interpolation of the absolute frame length performance data. Using these predicted values for each subject, means were then obtained for the men and for the women to provide an estimate of performance under the P and P+2 conditions.

The results of this interpolation procedure are shown in Tables 27, 28, 29 and 30 which contain the men's and women's agility run and ladder climb performance measures for the load-participation time combinations used in the study. Not only are the mean values for the estimated performances for the P and P+2 conditions included in these tables, but also the means for the absolute frame conditions are shown for comparison. The results of this analysis clearly suggest that the performances under the P condition were the poorest of the six measures for each load-participation time combination. When performance was predicted for the P+2 condition, the results indicated that the estimated performances were generally better than those for the P condition, and in some cases, the P+2 performances approached the best performance recorded for each load-participation combination. These results clearly suggest that the criterion used to predict the personalized frame length may be inappropriate. The addition of 1.25 inches (3.18 cm) to the waist back length appears to result in a frame length for which performances are inferior in comparison to performances under longer frames. The P+2 condition, which is represented as waist back length plus 3.25 inches (8.26 cm) appears to be a more appropriate criterion for assigning a frame length to a particular individual.

Even though the performance estimates for the P+2 condition were better than those for the P condition, they generally were not the best performance measures recorded. In an effort to better assess the effect of the body size-frame length interaction on performance, a second approach in which the absolute frame length conditions were normalized to waist back length was used. The

Table 27

Men's Agility Run Performance (sec) for Personalized, Personalized plus 2 inches, and Absolute Frame Length Conditions

Time	P ($\bar{X}$=18.6)	P+2 ($\bar{X}$=20.6)	Frame Length (in.) 18	20	22	24
			Load 1 (26 kg)			
0	8.14	8.05	8.09	8.01	8.00	8.06
25	8.08	7.98	7.97	7.91	7.99	7.95
50	8.04	7.91	8.00	7.99	7.90	7.91
			Load 2 (40 kg)			
0	8.75	8.63	8.73	8.70	8.62	8.56
25	8.82	8.73	8.85	8.78	8.71	8.56
50	8.88	8.71	8.85	8.84	8.72	8.54

Table 28

Women's Agility Run Performance (sec) for Personalized, Personalized plus 2 inches, and Absolute Frame Length Conditions

Time	P ($\bar{X}$=17.1)	P+2 ($\bar{X}$=19.1)	Frame Length (in.) 16	18	20	22
			Load 1 (26 kg)			
0	9.14	9.11	9.28	9.11	9.11	9.16
25	9.22	8.95	9.37	9.20	8.87	9.03
50	9.17	8.92	9.29	9.22	8.80	9.00
			Load 2 (33 kg)			
0	9.70	9.63	9.64	9.87	9.50	9.61
25	9.63	9.56	9.64	9.69	9.54	9.64
50	9.55	9.49	9.60	9.53	9.48	9.52

Table 29

Men's Ladder Climb Performance (sec) for Personalized, Personalized plus 2 inches, and Absolute Frame Length Conditions

	P	P+2	Frame Length (in.)			
Time	($\bar{X}$=18.6)	($\bar{X}$=20.6)	18	20	22	24
			Load 1 (26 kg)			
0	3.05	3.00	3.07	2.93	3.01	2.90
25	2.90	2.83	2.92	2.74	2.82	2.76
50	2.82	2.77	2.79	2.71	2.71	2.75
			Load 2 (40 kg)			
0	3.69	3.61	3.63	3.66	3.63	3.60
25	3.73	3.58	3.67	3.62	3.56	3.61
50	3.50	3.54	3.47	3.54	3.49	3.45

Table 30

Women's Ladder Climb Performance (sec) for Personalized, Personalized plus 2 inches, and Absolute Frame Length Conditions

	P	P+2	Frame Length (in.)			
Time	($\bar{X}$=17.1)	($\bar{X}$=19.1)	16	18	20	22
			Load 1 (26 kg)			
0	5.56	5.24	5.41	5.35	5.30	5.21
25	5.17	4.82	5.36	5.08	4.79	4.76
50	4.78	4.65	4.79	4.76	4.63	4.57
			Load 2 (40 kg)			
0	6.22	6.55	5.95	6.64	6.48	7.34
25	6.01	5.94	5.86	6.22	5.90	6.91
50	5.77	5.77	5.65	5.96	5.67	6.51

normalized values were derived simply by dividing the fixed frame length values by each individual's waist back length. These relative frame length measures were then correlated with the agility run and ladder climb performances for the various load-participation time combinations. These correlations are contained in Table 31. If, in fact, there was a clear trend present in the data such that performance was better under longer frame conditions, then a significant relationship should exist between the relative frame length measures and performance. The results of the correlation procedure clearly demonstrated that there was no such trend in the data. Of the 24 correlations contained in Table 31, only two were significant at the 0.05 level and these were still quite low. Consequently, it must be concluded from these results that there is no clear tendency for performances to be better under longer normalized frame lengths.

Table 31

Normalized Frame Length-Performance Correlation Values for the Various Load-Participation Time Combinations

	Men		Women	
Condition	Agility Run	Ladder Climb	Agility Run	Ladder Climb
Light Load				
0	0.08	-0.11	-0.17	-0.05
25	0.06	-0.12	-0.29*	-0.17
50	0.00	-0.08	-0.27*	-0.09
Heavy Load				
0	-0.03	-0.04	-0.13	0.17
25	-0.03	-0.01	-0.13	0.09
50	-0.08	-0.01	-0.13	0.08

* $P < 0.05$

DISCUSSION

The purpose of this study was to examine the effects of gender, backpack frame length, pack load, and participation time on combative movement performance and on walking mechanics. It was of particular interest in this study to determine if a single frame length is adequate for both male and female Army personnel, and, if so, whether the current standard frame length of 20 inches (50.8 cm) is the most appropriate length. Seventeen men and sixteen women performed two combative movement tests and both overground and treadmill walking under eight load-frame length combinations. The frame lengths used by the men ranged from 18 to 24 inches (45.7 to 61.0 cm) while those used by the women ranged from 16 to 22 inches (40.6 to 55.9 cm). The load conditions included a common load for the men and women of approximately 26 kg and a second load of 33 kg for the women and 40 kg for the men. Each test session was designed to provide continuous activity for 55 minutes and included three separate examinations of the combative movement tests, the agility run and ladder climb, and two periods of overground and treadmill walking. The mechanics of treadmill walking were studied by filming the subjects and subsequently quantifying a number of basic temporal and kinematic characteristics from the film.

The results of the study with respect to the gender factor were consistent with those from earlier studies by Nelson and Martin (ref. 4), Martin and Nelson,[6] and Martin, Nelson, and Shin (ref. 1). In general, male performance for the two combative movement tests was significantly better than that of the females. Average female performance was approximately 88% of the male performance for the agility run and 58% of the male performance for the ladder climb. Relative performance measures reported by Nelson and Martin (ref. 4) for these two tests were 80% and 43% for approximately the same load conditions. The results of this study confirm that the male-female performance differences are more pronounced for the ladder climb when compared to the agility run. In addition, it is quite clear that careful consideration should be given to the relative loads carried by men and women. In general, the loads carried by females should be less than those carried by males and, whenever feasible, loads should be adjusted according to the lean body mass of each individual.

For treadmill walking, male and female values for temporal and kinematic variables under investigation were approximately 5% different from one another. Men demonstrated greater stride lengths, single leg contact times, swing times, and trunk angles and lower stride rates than the women. Only for double support time did the difference between the men and women lack significance. This male-female difference essentially means that females will generally require a greater number of steps to cover a given distance than the males during walking with no cadence restrictions such as on a training hike. As Martin et al. (ref. 1) noted, this may have some impact on the metabolic cost of performing such a hike and may place the females at a disadvantage, particularly under heavy loads and for long durations.

[6] Martin, P.E. and R.C. Nelson. Volume III. Effects of Gender, Load, and Backpack on the Temporal and Kinematic Characteristics of Walking Gait (Tech. Rep. NATICK/TR-82/021). Natick, Massachusetts: US Army Natick Research and Development Laboratories, April 1982.

The effect of load on male and female performance was also quite consistent with past research findings. The results of this study showed that agility run and ladder climb performance declined significantly as load was increased. The men demonstrated 9% and 26% decreases in agility run and ladder climb performances, respectively, for the 14-kg load increase to which they were subjected. The female performances declined by 5% and 25% for the same tests when load was increased by approximately 7 kg. The results of these tests and of earlier studies confirm the significant effect that load can have on the ability to generate rapid movements. The obvious implication, of course, is to keep load magnitude as low as possible in those situations in which rapid movement and quick reaction are important.

The results of the treadmill walking analysis indicated that increased load produced significant modifications in the mechanics of walking. Nevertheless, these modifications were quite small (approximately 1%) for the load changes imposed on the subjects in this study. Once again these changes were consistent with earlier findings by Martin and Nelson (ref. 6). While the results indicated statistically significant modifications in walking mechanics due to load increases, the practical importance of these modifications is open to question. Although, at first inspection, these small modifications may seem trivial, they may take on increasing importance as duration of walking increases.

A third factor under consideration in this study was that of participation time. Martin et al. (ref. 1) had also considered the effect of duration of participation on walking and running mechanics and stability measures during quiet standing, but to a much more limited extent. In general, their multiple samples of performance were separated by no more than a few minutes. Consequently, their results indicated few significant effects associated with the participation time factor. Nevertheless, they suggested that modifications in performance may result only after considerably longer periods of participation. The present study more effectively evaluated the participation time factor by having subjects perform continuously for approximately one hour and sampling combative movement performance and treadmill walking three and two times, respectively, during the one-hour activity period. Surprisingly, the results of the study demonstrated that few significant differences were attributed to increased time of participation, thereby suggesting that there was little effect on performance due to fatigue. For the performance tests, the only notable change was a slight improvement in performance measures as time increased, which was exactly opposite of what was expected. Despite having a brief warmup prior to each test session and having included an orientation session in which the test movements were practiced prior to the data collection sessions, it appears that possible warmup and learning effects influenced the data. This seems to have been particularly true for the ladder climb, which in general has been found to be a more difficult task for the subjects to learn to perform skillfully when compared with the agility run. While learning and warmup effects may have had a confounding influence on the data, it seems reasonable to conclude that the one-hour activity period used in this study did not prevent the subjects from giving their best performances for the brief duration of the agility run and ladder climb tests.

With respect to walking mechanics, only minor adjustments were attributed to increased time of participation. The men demonstrated significant changes in stride length, stride rate, and swing time while the women displayed no significant changes. Although the effect of increased participation time produced trends similar to those for increased load, the observed changes were considerably smaller and, in general, can be considered to be of limited practical importance. Nevertheless, there was some tendency for the participation time factor to interact with the load and frame length factors such that the effects due to these latter two factors tended to increase with increased time of participation. Consequently, the results of this study lend some support to the suggestion posed by Martin et al. (ref. 1) that fatigue due to continued participation will accentuate the effects due to other factors such as frame length and load.

The fourth and final factor under investigation in this study, frame length, was of special interest since the main purpose of the study was to determine if a single frame length is suitable for all Army personnel. The results for the performance tests suggested a tendency for performances to be somewhat better for the longer frame lengths. The men demonstrated their best performances for both the agility run and ladder climb under the 24-inch frame condition. The women, on the other hand, tended to have their best agility run and ladder climb performances under the 20-inch frame condition. Even though these trends were present, none of these differences were significant statistically. Of the six variables used to describe walking mechanics, a significant effect due to frame length was found only for trunk angle. Even though trunk angle showed some significant changes due to frame length, the differences were quite small. In general then, modifications in frame length produced only minor modifications in walking patterns with no consistent trends surfacing.

To further examine the effect of frame length on performance and to consider the interaction of frame length and body size, the frame length values were normalized to body size utilizing the waist back length measure for each individual. Two approaches were utilized to examine this effect. The first involved predicting performance scores for a personalized frame length and for a personalized plus two inches frame condition. These P and P+2 conditions were utilized by Martin et al. (ref. 1) when they examined the influence of frame length on performance. The second approach involved correlating the normalized frame length measures with the performance scores. The results of the first approach showed that the predicted performance measures for the P frame condition were generally poorer than the recorded performances for the absolute frame lengths under investigation. This clearly suggested that the addition of 1.25 inches to the waist back length measure is an inappropriate criterion for assigning a personalized frame length. The estimated performances for the P+2 condition (waist back length plus 3.75 inches) were considerably better than those for the P condition suggesting it would be a more appropriate criterion for assigning a personalized frame length for an individual. Nevertheless, the performance estimates for the P+2 condition were still inferior to recorded performances for selected absolute frame lengths.

The results of the correlation procedure failed to indicate a consistent trend between the normalized frame lengths and performance. No correlation value exceeded ± 0.29 and many approached zero. It was expected that an inverse relationship would exist between the two variables which would indicate that an increase in frame length relative to waist back length (i.e. a longer relative frame length) would result in improved performance scores. This was not found to be the case for the agility run and ladder climb performances.

The combination of the results of these two appraoches may well be suggesting that relatively short frames may be detrimental to performance, but that as frames are increased beyond a certain length relative to body size, there is little advantage to be gained. In addition, the results may also indicate that each individual has his own frame length for which performance is maximized. The relationship between this length and body size may vary from subject to subject. As one would expect, there seem to be other factors which have an effect on which frame length is ideal for an individual.

CONCLUSIONS

In conclusion, the results of this study suggest that one frame length is not adequate for all Army personnel. While there was a tendency for female performance to be somewhat better under the 20-inch frame condition in comparison with the other three under investigation, the results for the men suggested that a frame longer than 20 inches would be more advantageous. Nevertheless, it is recommended that a frame which can be adjusted to each individual's preferences would be the best solution to the frame length problem. Some general guidelines for adjusting the frame to body size could then be provided, but the individual could ultimately decide upon the frame length which seems most appropriate for the particular task to be performed and the loads to be carried. Although subjective evaluations of comfort were not included in this study, it is believed that they would have a major influence on the manner in which individuals adjust their frames. Consequently, it is felt that any future research evaluating the influence of frame length on performance should include some form of subjective evaluations of comfort.

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APPENDIX A

Descriptions of the

Anthropometric Variables

This appendix contains a description of the measurement procedures and/or definitions of the fifteen anthropometric variables for which measures were taken in this study. These descriptions are based on the 1966 and 1977 reports on the anthropometry of Army men and women (ref. 2 and 3) with the exception of waist back length, whose definition was modified slightly in an earlier study (ref. 1) and was then retained for use in this study. All height and circumference measures were taken to the nearest millimeter. Weight was measured to the nearest tenth of a kilogram.

Stature: The subject stood erect, with heels together and head level. Stature was measured as the vertical distance from the floor to the top of the head (vertex). An anthropometer was used, with the anthropometer arm firmly touching the scalp to compress the hair.

Weight: The subject was weighed on scales, while wearing only shorts and t-shirt.

Waist Back Length: The subject stood erect, with head level. Waist back length was measured as the vertical distance along the surface of the back from the cervicale point (the bony protrusion of the 7th cervical vertebra at the base of the neck) to the level of the waist as indicated by the level of the navel.

Cervicale Height: The subject stood erect, with heels together and head level. Cervical height was measured as the vertical distance from the floor to the cervicale point (the bony protrusion of the 7th cervical vertebra at the base of the neck).

Shoulder Height: The subject stood erect, with heels together and head level. Shoulder height was measured as the vertical distance from the floor to the outer point (acromion) of the right shoulder.

Crotch Height: The subject stood erect, with his feet initially apart and then brought together after the anthropometer was in place. Crotch height was measured as the vertical distance from the floor (or standing surface) to the crotch. An anthropometer was used, with the anthropometer arm firmly in contact with the highest point in the crotch.

Waist Height: Subject stood erect, with heels together. For the men, waist height was measured as the vertical distance from the floor to the upper edge (illiac crest) of the right hip bone. For the women, the measure was the vertical distance from the floor to the level of the navel.

Buttock Height: The subject stood erect with heels together. The measure was taken as the vertical distance from the floor to the point of maximum protrusion of the buttocks.

Sitting Height: The subject sat erect, with head level, and with the feet resting on a surface adjusted so that the knees were bent at right angles. Sitting height was measured as the vertical distance from the sitting surface to the top of the head (vertex). An anthropometer was used, with the anthropometer arm firmly touching the scalp to compress the hair.

Shoulder Circumference: The subject stood erect, with his arms hanging at his sides. The maximum horizontal circumference of the shoulders was measured at the level of the bulges of the deltoid muscles in the upper arms.

Chest Circumference at Scye: The subject stood erect, with his arms initially raised and then lowered after the tape was in place. The maximum horizontal circumference of the chest was measured with the tape high in the armpits.

Chest/Bust Circumference: The horizontal circumference of the trunk was measured with the tape passing over the nipples during normal breathing.

Waist Circumference: The subject stood erect, with the abdomen relaxed. The maximum horizontal circumference of the waist was measured at the level of the navel (omphalion).

Hip Circumference: The subject stood erect, with heels together. The maximum horizontal circumference of the hip was measured at the level of the greatest protrusion of the buttock muscles.

Interscye Breadth: The subject stood erect, with his arms at his sides. Interscye breadth was measured as the horizontal distance across the surface of the back between the upper ends of the armpit creases (scye points).

APPENDIX B

Mean Values for the Performance Tests
and Variables of the Walking Analysis
for the Men and Women

Table B-1

Mean Values for Agility Run (sec) for Men

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
0	8.09	8.01	8.00	8.06
25	7.97	7.91	7.99	7.95
50	8.00	7.99	7.90	7.91

Load 2 (40 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
0	8.73	8.70	8.62	8.56
25	8.85	8.78	8.71	8.56
50	8.85	8.24	8.72	8.54

Main Means

Frame Length	18	20	22	24
	8.42	8.37	8.32	8.26

Load	26	40
	7.98	8.70

Participation Time	0	25	50
	8.35	8.34	8.34

Overall Mean for Men 8.34

Table B-2

Mean Values for Agility Run (sec) for Women

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
0	9.28	9.11	9.11	9.16
25	9.37	9.20	8.87	9.02
50	9.29	9.22	8.80	9.00

Load 2 (33 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
0	9.64	9.87	9.50	9.61
25	9.64	9.69	9.54	9.64
50	9.60	9.53	9.48	9.52

Main Means

Frame Length	16	18	20	22
	9.47	9.44	9.22	9.33

Load	26	33
	9.12	9.61

Participation Time	0	25	50
	9.41	9.37	9.30

Overall Mean for Women 9.36

Table B-3

Mean Values for Ladder Climb (sec) for Men

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
0	3.07	2.93	3.01	2.90
25	2.92	2.74	2.82	2.76
50	2.79	2.71	2.71	2.75

Load 2 (40 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
0	3.63	3.66	3.63	3.60
25	3.67	3.62	3.56	3.61
50	3.47	3.54	3.49	3.45

Main Means

Frame Length

18	20	22	24
3.26	3.20	3.20	3.18

Load

26	40
2.84	3.58

Participation Time

0	25	50
3.30	3.21	3.12

Overall Mean for Men 3.21

Table B-4

Mean Values for Ladder Climb (sec) for Women

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
0	5.41	5.35	5.30	5.21
25	5.36	5.08	4.79	4.76
50	4.79	4.76	4.63	4.57

Load 2 (33 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
0	5.95	6.64	6.48	7.34
25	5.86	6.22	5.90	6.91
50	5.65	5.96	5.67	6.51

Main Means

Frame Length

16	18	20	22
5.50	5.67	5.46	5.88

Load

26	33
5.00	6.26

Participation Time

0	25	50
5.96	5.61	5.32

Overall Mean for Women 5.63

Table B-5

Mean Values for Stride Length (m) for Men

Cell Means

Load 1 (26 kg)

Participation Time (min)		Frame Length (in.) 18	20	22	24
	5	0.804	0.810	0.810	0.805
	45	0.797	0.803	0.803	0.805

Load 2 (40 kg)

Participation Time (min)		Frame Length (in.) 18	20	22	24
	5	0.793	0.803	0.795	0.799
	45	0.788	0.798	0.787	0.796

Main Means

Frame Length	18	20	22	24
	0.796	0.804	0.799	0.801
Load	26	40		
	0.805	0.795		
Participation Time	5	45		
	0.803	0.797		

Overall Mean for Men 0.800

Table B-6

Mean Values for Stride Length (m) for Women

Cell Means

Load 1 (26 kg)

Frame Length (in.)

Participation Time (min)		16	18	20	22
	5	0.763	0.762	0.760	0.762
	45	0.759	0.765	0.762	0.761

Load 2 (33 kg)

Frame Length (in.)

Participation Time (min)		16	18	20	22
	5	0.755	0.750	0.745	0.755
	45	0.760	0.750	0.748	0.758

Main Means

Frame Length	16	18	20	22
	0.759	0.757	0.754	0.759

Load	26	33
	0.762	0.753

Participation Time	5	45
	0.757	0.758

Overall Mean for Women 0.757

Table B-7

Mean Values for Stride Rate (str/sec) for Men

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
5	1.95	1.93	1.93	1.95
45	1.97	1.95	1.95	1.95

Load 2 (40 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
5	1.98	1.95	1.97	1.96
45	1.99	1.97	1.99	1.97

Main Means

Frame Length

18	20	22	24
1.97	1.95	1.96	1.96

Load

26	40
1.95	1.97

Participation Time

5	45
1.95	1.97

Overall Mean for Men 1.96

Table B-8

Mean Values for Stride Rate (str/sec) for Women

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	2.05	2.06	2.06	2.06
45	2.06	2.05	2.06	2.06

Load 2 (33 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	2.08	2.09	2.11	2.08
45	2.06	2.09	2.09	2.07

Main Means

Frame Length	16	18	20	22
	2.06	2.07	2.08	2.07

Load	26	33
	2.06	2.08

Participation Time	5	45
	2.07	2.07

Overall Mean for Women 2.07

Table B-9

Mean Values for Single Leg Contact Time (msec) for Men

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
5	654	661	661	658
45	652	652	656	657

Load 2 (40 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
5	659	666	660	665
45	658	664	653	668

Main Means

Frame Length	18	20	22	24
	656	661	657	662
Load	26	40		
	656	662		
Participation Time	5	45		
	660	658		

Overall Mean for Men 659

Table B-10

Mean Values for Single Leg Contact Time (msec) for Women

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	625	623	621	625
45	621	628	624	624

Load 2 (33 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	624	622	618	629
45	630	626	622	628

Main Means

Frame Length	16	18	20	22
	625	625	621	626

Load	26	33
	624	625

Participation Time	5	45
	623	625

Overall Mean for Women 624

Table B-11

Mean Values for Swing Time (msec) for Men

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
5	374	375	375	371
45	366	374	370	372

Load 2 (40 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
5	355	361	356	356
45	349	355	352	349

Main Means

Frame Length	18	20	22	24
	361	366	363	362
Load	26	40		
	372	354		
Participation Time	5	45		
	365	361		

Overall Mean for Men 363

Table B-12

Mean Values for Swing Time (msec) for Women

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	350	351	351	348
45	350	350	350	348

Load 2 (33 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	342	336	334	337
45	341	332	335	341

Main Means

Frame Length	16	18	20	22
	345	342	342	343
Load	26	33		
	349	337		
Participation Time	5	45		
	343	343		

Overall Mean for Women 343

Table B-13

Mean Values for Double Support Time (msec) for Men

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
5	142	144	143	143
45	143	139	141	143

Load 2 (40 kg)

Participation Time (min)	Frame Length (in.) 18	20	22	24
5	153	155	151	156
45	154	155	153	161

Main Means

Frame Length	18	20	22	24
	148	148	147	151

Load	26	40
	142	155

Participation Time	5	45
	148	149

Overall Mean for Men 149

Table B-14

Mean Values for Double Support Time (msec) for Women

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	139	138	138	139
45	137	142	139	138

Load 2 (33 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	142	142	144	147
45	148	149	143	145

Main Means

Frame Length	16	18	20	22
	142	143	141	142

Load	26	33
	139	145

Participation Time	5	45
	141	143

Overall Mean for Women 142

Table B-15

Mean Values for Trunk Angle (deg) for Men

Cell Means

Load 1 (26 kg)

Frame Length (in.)

		18	20	22	24
Participation Time (min)	5	84.5	85.5	85.2	85.7
	45	83.9	86.2	86.0	85.9

Load 2 (40 kg)

Frame Length (in.)

		18	20	22	24
Participation Time (min)	5	78.7	81.4	79.7	81.0
	45	77.3	81.6	79.5	80.1

Main Means

Frame Length	18	20	22	24
	81.1	83.7	82.6	83.2

Load	26	40
	85.4	79.9

Participation Time	5	45
	82.7	82.6

Overall Mean for Men 82.6

Table B-16

Mean Values for Trunk Angle (deg) for Women

Cell Means

Load 1 (26 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	83.7	83.3	83.5	81.7
45	84.3	82.9	83.7	81.2

Load 2 (33 kg)

Participation Time (min)	Frame Length (in.) 16	18	20	22
5	79.4	78.6	80.2	78.2
45	78.6	78.2	80.1	77.1

Main Means

Frame Length

16	18	20	22
81.5	80.7	81.9	79.5

Load

26	33
83.0	78.8

Participation Time

5	45
81.1	80.8

Overall Mean for Women 80.9

APPENDIX C

ANOVA Summary Tables

Table C-1

ANOVA Summary of Men's Agility Run Performance for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	16	8.870	
Within Subjects			
Frame	3	0.452	2.209
Error	48	0.205	
Load	1	53.214	50.509*
Error	16	1.053	
Frame x Load	3	0.277	1.102
Error	48	0.252	
Time	2	0.113×10^{-2}	0.009
Error	32	0.119	
Frame x Time	6	0.457×10^{-1}	0.800
Error	96	0.571×10^{-1}	
Load x Time	2	0.323	2.440
Error	32	0.132	
Frame x Load x Time	6	0.119×10^{-1}	0.316
Error	96	0.378×10^{-1}	

* $P < 0.05$

Table C-2

ANOVA Summary of Women's Agility Run Performance for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	15	17.964	
Within Subjects			
Frame	3	1.243	2.177
Error	45	0.571	
Load	1	22.796	16.919*
Error	15	1.347	
Frame x Load	3	0.335	0.344
Error	45	0.973	
Time	2	0.367	3.048
Error	30	0.120	
Frame x Time	6	0.425×10^{-1}	0.680
Error	90	0.625×10^{-1}	
Load x Time	2	0.263×10^{-1}	0.573
Error	30	0.458×10^{-1}	
Frame x Load x Time	6	0.227	2.644*
Error	90	0.858×10^{-1}	

* $P < 0.05$

Table C-3

ANOVA Summary of Agility Run Performance
for Gender, Frame Length, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Gender	1	84.755	27.311*
Error	31	3.103	
Within Subjects			
Frame	2	0.553	1.792
Gender x Frame	2	0.268	0.870
Error	62	0.308	
Time	2	0.266	4.482*
Gender x Time	2	0.018	0.296
Error	62	0.059	
Frame x Time	4	0.083	1.824
Gender x Frame x Time	4	0.157	3.432*
Error	124	0.046	

* $P < 0.05$

Table C-4

ANOVA Summary of Men's Agility Run Performance for Frame Length and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	16	2.211	
Within Subjects			
Frame	2	0.518×10^{-1}	0.227
Error	32	0.228	
Time	2	0.875×10^{-1}	1.825
Error	32	0.480×10^{-1}	
Frame x Time	4	0.350×10^{-1}	1.093
Error	64	0.321×10^{-1}	

* $P < 0.05$

Table C-5

ANOVA Summary of Women's Agility Run Performance
for Frame Length and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	15	4.055	
Within Subjects			
Frame	2	0.769	1.952
Error	30	0.394	
Time	2	0.196	2.741
Error	30	0.717×10^{-1}	
Frame x Time	4	0.205	3.405*
Error	60	0.603×10^{-1}	

* $P < 0.05$

Table C-6

ANOVA Summary of Men's Ladder Climb Performance for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
<u>Between Subjects</u>			
Error	16	6.557	
<u>Within Subjects</u>			
Frame	3	0.122	0.162
Error	48	0.751	
Load	1	54.889	27.506*
Error	16	2.000	
Frame x Load	3	0.968×10^{-1}	0.172
Error	48	0.564	
Time	2	1.186	26.505*
Error	32	0.448×10^{-1}	
Frame x Time	6	0.270×10^{-1}	0.631
Error	96	0.428×10^{-1}	
Load x Time	2	0.199	3.406*
Error	32	0.584×10^{-1}	
Frame x Load x Time	6	0.178×10^{-1}	0.362
Error	96	0.490×10^{-1}	

* $P < 0.05$

Table C-7

ANOVA Summary of Women's Ladder Climb Performance for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	15	55.989	
Within Subjects			
Frame	3	3.524	0.612
Error	45	5.755	
Load	1	151.250	22.770*
Error	15	6.642	
Frame x Load	3	8.651	1.575
Error	45	5.492	
Time	2	13.146	21.206*
Error	30	0.620	
Frame x Time	6	0.351	0.645
Error	90	0.543	
Load x Time	2	0.264×10^{-1}	0.081
Error	30	0.327	
Frame x Load x Time	6	0.161	0.325
Error	90	0.496	

* $P < 0.05$

Table C-8

ANOVA Summary of Ladder Climb Performance
for Gender, Frame Length, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Gender	1	321.882	38.513*
Error	31	8.358	
Within Subjects			
Frame	2	0.720	0.565
Gender x Frame	2	0.134	0.105
Error	62	1.273	
Time	2	4.979	31.067*
Gender x Time	2	0.850	5.304*
Error	62	0.160	
Frame x Time	4	0.053	0.421
Gender x Frame x Time	4	0.024	0.190
Error	124	0.126	

* $P < 0.05$

Table C-9

ANOVA Summary of Men's Stride Length
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	16	0.192×10^{-1}	
Within Subjects			
Frame	3	0.829×10^{-3}	1.429
Error	48	0.580×10^{-3}	
Load	1	0.678×10^{-2}	14.713*
Error	16	0.461×10^{-3}	
Frame x Load	3	0.313×10^{-3}	0.898
Error	48	0.349×10^{-3}	
Time	1	0.212×10^{-2}	5.837*
Error	16	0.364×10^{-3}	
Frame x Time	3	0.141×10^{-3}	1.041
Error	48	0.135×10^{-3}	
Load x Time	1	0.288×10^{-5}	0.016
Error	16	0.186×10^{-3}	
Frame x Load x Time	3	0.224×10^{-4}	0.066
Error	48	0.338×10^{-3}	

* $P < 0.05$

Table C-10

ANOVA Summary of Women's Stride Length
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
<u>Between Subjects</u>			
Error	15	0.960×10^{-2}	
<u>Within Subjects</u>			
Frame	3	0.391×10^{-3}	0.945
Error	45	0.414×10^{-3}	
Load	1	0.529×10^{-2}	7.407*
Error	15	0.715×10^{-3}	
Frame x Load	3	0.544×10^{-3}	1.631
Error	45	0.334×10^{-3}	
Time	1	0.113×10^{-3}	0.398
Error	15	0.283×10^{-3}	
Frame x Time	3	0.138×10^{-4}	0.063
Error	45	0.220×10^{-3}	
Load x Time	1	0.879×10^{-4}	0.532
Error	15	0.165×10^{-3}	
Frame x Load x Time	3	0.785×10^{-4}	0.575
Error	45	0.137×10^{-3}	

* $P < 0.05$

Table C-11

ANOVA Summary of Stride Length
for Gender, Frame Length, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Gender	1	0.900×10^{-1}	17.198*
Error	31	0.523×10^{-2}	
Within Subjects			
Frame	2	0.828×10^{-4}	0.186
Gender x Frame	2	0.372×10^{-3}	0.834
Error	62	0.446×10^{-3}	
Time	1	0.547×10^{-3}	3.807
Gender x Time	1	0.100×10^{-2}	6.972*
Error	31	0.144×10^{-3}	
Frame x Time	2	0.136×10^{-4}	0.088
Gender x Frame x Time	2	0.120×10^{-4}	0.078
Error	62	0.155×10^{-3}	

* $P < 0.05$

Table C-12

ANOVA Summary of Men's Stride Rate
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	16	0.116	
Within Subjects			
Frame	3	0.578×10^{-2}	1.529
Error	48	0.378×10^{-2}	
Load	1	0.435×10^{-1}	13.646*
Error	16	0.319×10^{-2}	
Frame x Load	3	0.178×10^{-2}	0.841
Error	48	0.211×10^{-2}	
Time	1	0.132×10^{-1}	5.904*
Error	16	0.224×10^{-2}	
Frame x Time	3	0.868×10^{-3}	1.060
Error	48	0.819×10^{-3}	
Load x Time	1	0.453×10^{-4}	0.040
Error	16	0.113×10^{-2}	
Frame x Load x Time	3	0.153×10^{-3}	0.076
Error	48	0.200×10^{-2}	

* $P < 0.05$

Table C-13

ANOVA Summary of Women's Stride Rate
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	15	0.730×10^{-1}	
Within Subjects			
Frame	3	0.301×10^{-2}	0.955
Error	45	0.315×10^{-2}	
Load	1	0.424×10^{-1}	7.894*
Error	15	0.537×10^{-2}	
Frame x Load	3	0.429×10^{-2}	1.741
Error	45	0.246×10^{-2}	
Time	1	0.101×10^{-2}	0.464
Error	15	0.218×10^{-2}	
Frame x Time	3	0.136×10^{-3}	0.080
Error	45	0.170×10^{-2}	
Load x Time	1	0.837×10^{-3}	0.651
Error	15	0.129×10^{-2}	
Frame x Load x Time	3	0.673×10^{-3}	0.662
Error	45	0.102×10^{-2}	

* $P < 0.05$

Table C-14

ANOVA Summary of Stride Rate
for Gender, Frame Length, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Gender	1	0.571	17.311*
Error	31	0.330×10^{-1}	
Within Subjects			
Frame	2	0.662×10^{-3}	0.216
Gender x Frame	2	0.296×10^{-2}	0.965
Error	62	0.307×10^{-2}	
Time	1	0.344×10^{-2}	3.731
Gender x Time	1	0.683×10^{-2}	7.408*
Error	31	0.921×10^{-3}	
Frame x Time	2	0.941×10^{-4}	0.092
Gender x Frame x Time	2	0.648×10^{-4}	0.063
Error	62	0.103×10^{-2}	

* $P < 0.05$

Table C-15

ANOVA Summary of Men's Single Leg Contact Time for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	16	0.139×10^{-1}	
Within Subjects			
Frame	3	0.563×10^{-3}	1.089
Error	48	0.517×10^{-3}	
Load	1	0.201×10^{-2}	5.976*
Error	16	0.336×10^{-3}	
Frame x Load	3	0.463×10^{-3}	1.737
Error	48	0.266×10^{-3}	
Time	1	0.574×10^{-3}	1.635
Error	16	0.351×10^{-3}	
Frame x Time	3	0.184×10^{-3}	1.074
Error	48	0.171×10^{-3}	
Load x Time	1	0.118×10^{-3}	0.609
Error	16	0.193×10^{-3}	
Frame x Load x Time	3	0.608×10^{-4}	0.346
Error	48	0.176×10^{-3}	

* $P < 0.05$

Table C-16

ANOVA Summary of Women's Single Leg Contact Time for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	15	0.666×10^{-2}	
Within Subjects			
Frame	3	0.324×10^{-3}	0.822
Error	45	0.393×10^{-3}	
Load	1	0.353×10^{-4}	0.083
Error	15	0.425×10^{-3}	
Frame x Load	3	0.184×10^{-3}	0.587
Error	45	0.313×10^{-3}	
Time	1	0.278×10^{-3}	0.846
Error	15	0.329×10^{-3}	
Frame x Time	3	0.900×10^{-4}	0.797
Error	45	0.113×10^{-3}	
Load x Time	1	0.114×10^{-3}	0.659
Error	15	0.173×10^{-3}	
Frame x Load x Time	3	0.118×10^{-3}	0.781
Error	45	0.151×10^{-3}	

* $P < 0.05$

Table C-17

ANOVA Summary of Single Leg Contact Time
for Gender, Frame Length, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Gender	1	0.495×10^{-1}	12.324*
Error	31	0.402×10^{-2}	
Within Subjects			
Frame	2	0.109×10^{-3}	0.237
Gender x Frame	2	0.180×10^{-3}	0.391
Error	62	0.461×10^{-3}	
Time	1	0.123×10^{-3}	0.677
Gender x Time	1	0.743×10^{-3}	4.090
Error	31	0.182×10^{-3}	
Frame x Time	2	0.983×10^{-4}	0.783
Gender x Frame x Time	2	0.754×10^{-4}	0.601
Error	62	0.126×10^{-3}	

* $P < 0.05$

Table C-18

ANOVA Summary of Men's Swing Time
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	16	0.485×10^{-2}	
Within Subjects			
Frame	3	0.342×10^{-3}	1.214
Error	48	0.281×10^{-3}	
Load	1	0.225×10^{-1}	60.314*
Error	16	0.374×10^{-3}	
Frame x Load	3	0.201×10^{-4}	0.068
Error	48	0.297×10^{-3}	
Time	1	0.121×10^{-2}	8.126*
Error	16	0.149×10^{-3}	
Frame x Time	3	0.567×10^{-4}	0.503
Error	48	0.113×10^{-3}	
Load x Time	1	0.872×10^{-4}	0.735
Error	16	0.119×10^{-3}	
Frame x Load x Time	3	0.781×10^{-4}	0.350
Error	48	0.223×10^{-3}	

* $P < 0.05$

Table C-19

ANOVA Summary of Women's Swing Time
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	15	0.253×10^{-2}	
Within Subjects			
Frame	3	0.138×10^{-3}	0.721
Error	45	0.191×10^{-3}	
Load	1	0.978×10^{-2}	21.480*
Error	15	0.455×10^{-3}	
Frame x Load	3	0.261×10^{-3}	0.793
Error	45	0.329×10^{-3}	
Time	1	0.564×10^{-5}	0.074
Error	15	0.763×10^{-4}	
Frame x Time	3	0.595×10^{-4}	0.336
Error	45	0.177×10^{-3}	
Load x Time	1	0.000	0.000
Error	15	0.195×10^{-3}	
Frame x Load x Time	3	0.401×10^{-4}	0.343
Error	45	0.117×10^{-3}	

* $P < 0.05$

Table C-20

ANOVA Summary of Swing Time
for Gender, Frame Length, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Gender	1	0.261×10^{-1}	18.524*
Error	31	0.141×10^{-2}	
Within Subjects			
Frame	2	0.934×10^{-4}	0.431
Gender x Frame	2	0.121×10^{-3}	0.558
Error	62	0.217×10^{-3}	
Time	1	0.306×10^{-3}	3.481
Gender x Time	1	0.180×10^{-3}	2.047
Error	31	0.878×10^{-4}	
Frame x Time	2	0.519×10^{-4}	0.335
Gender x Frame x Time	2	0.577×10^{-4}	0.372
Error	62	0.155×10^{-3}	

* $P < 0.05$

Table C-21

ANOVA Summary of Men's Double Support Time
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	16	0.140×10^{-2}	
Within Subjects			
Frame	3	0.187×10^{-3}	0.901
Error	48	0.208×10^{-3}	
Load	1	0.109×10^{-1}	44.698*
Error	16	0.243×10^{-3}	
Frame x Load	3	0.115×10^{-3}	0.558
Error	48	0.205×10^{-3}	
Time	1	0.712×10^{-5}	0.082
Error	16	0.866×10^{-4}	
Frame x Time	3	0.589×10^{-4}	0.649
Error	48	0.907×10^{-4}	
Load x Time	1	0.222×10^{-3}	1.850
Error	16	0.120×10^{-3}	
Frame x Load x Time	3	0.303×10^{-4}	0.351
Error	48	0.862×10^{-4}	

* $P < 0.05$

Table C-22

ANOVA Summary of Women's Double Support Time for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	15	0.604×10^{-3}	
Within Subjects			
Frame	3	0.339×10^{-4}	0.208
Error	45	0.163×10^{-3}	
Load	1	0.265×10^{-2}	11.650*
Error	15	0.228×10^{-3}	
Frame x Load	3	0.235×10^{-4}	0.138
Error	45	0.170×10^{-3}	
Time	1	0.214×10^{-3}	1.379
Error	15	0.155×10^{-3}	
Frame x Time	3	0.125×10^{-3}	2.126
Error	45	0.587×10^{-4}	
Load x Time	1	0.391×10^{-4}	0.240
Error	15	0.163×10^{-3}	
Frame x Load x Time	3	0.986×10^{-4}	0.747
Error	45	0.132×10^{-3}	

* $P < 0.05$

Table C-23

ANOVA Summary of Double Support Time
for Gender, Frame Length, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Gender	1	0.486×10^{-3}	0.890
Error	31	0.546×10^{-3}	
Within Subjects			
Frame	2	0.164×10^{-4}	0.100
Gender x Frame	2	0.140×10^{-5}	0.009
Error	62	0.164×10^{-3}	
Time	1	0.505×10^{-8}	0.000
Gender x Time	1	0.158×10^{-3}	1.601
Error	31	0.986×10^{-4}	
Frame x Time	2	0.758×10^{-4}	0.911
Gender x Frame x Time	2	0.266×10^{-4}	0.320
Error	62	0.831×10^{-4}	

* $P < 0.05$

Table C-24

ANOVA Summary of Men's Trunk Angle
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	16	141.056	
Within Subjects			
Frame	3	84.293	7.971*
Error	48	10.575	
Load	1	2009.972	177.292*
Error	16	11.337	
Frame x Load	3	11.790	1.042
Error	48	11.318	
Time	1	1.384	0.395
Error	16	3.506	
Frame x Time	3	7.578	4.195*
Error	48	1.807	
Load x Time	1	13.147	4.184
Error	16	3.142	
Frame x Load x Time	3	0.211	0.130
Error	48	1.628	

* P < 0.05

Table C-25

ANOVA Summary of Women's Trunk Angle
for Frame Length, Load, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Error	15	42.611	
Within Subjects			
Frame	3	69.318	4.465*
Error	45	15.523	
Load	1	1150.482	11.249*
Error	15	10.342	
Frame x Load	3	8.755	1.042
Error	45	8.400	
Time	1	5.435	2.469
Error	15	2.201	
Frame x Time	3	2.621	1.608
Error	45	1.630	
Load x Time	1	5.091	2.599
Error	15	1.958	
Frame x Load x Time	3	1.517	0.887
Error	45	1.710	

* P < 0.05

Table C-26

ANOVA Summary of Trunk Angle
for Gender, Frame Length, and Participation Time

SOURCE OF VARIANCE	df	M.S.	F
Between Subjects			
Gender	1	313.165	8.176*
Error	31	38.305	
Within Subjects			
Frame	2	28.500	3.284*
Gender x Frame	2	39.776	4.584*
Error	62	8.677	
Time	1	0.153	0.077
Gender x Time	1	3.777	1.915
Error	31	1.973	
Frame x Time	2	4.549	4.051*
Gender x Frame x Time	2	2.354	2.096
Error	62	1.123	

* $P < 0.05$

APPENDIX D

Individual Waist Back and Personalized Frame Length Data

Men

Subject	Waist Back Length (cm)	Personalized Frame Length (cm)	(in)
1	43.1	46.3	18.2
2	42.7	45.9	18.1
3	41.3	44.5	17.5
4	48.1	51.3	20.2
5	43.9	47.1	18.5
6	45.3	48.5	19.1
7	47.6	50.8	20.0
8	42.7	45.9	18.1
9	46.8	50.0	19.7
10	45.9	49.1	19.3
11	44.6	47.8	18.8
12	44.8	48.0	18.9
13	40.1	43.3	17.0
14	46.6	49.8	19.6
15	40.7	43.9	17.3
16	43.3	46.5	18.3
17	43.6	46.8	18.4
$\bar{X}$	44.2	47.4	18.6
S.D.	2.4	2.4	0.9

Women

Subject	Waist Back Length (cm)	Personalized Frame Length (cm)	(in)
1	43.3	46.5	18.3
2	38.6	41.8	16.4
3	40.6	43.8	17.2
4	41.0	44.2	17.4
5	44.9	48.1	18.9
6	36.9	40.1	15.8
7	40.6	43.8	17.2
8	39.8	43.0	16.9
9	40.2	43.4	17.1
10	42.4	45.6	17.9
11	37.4	40.6	16.0
12	40.6	43.8	17.2
13	37.0	40.2	15.8
14	40.4	43.6	17.2
15	41.5	44.7	17.6
16	39.5	42.7	16.8
$\bar{X}$	40.3	43.5	17.1
S.D	2.2	2.2	0.9